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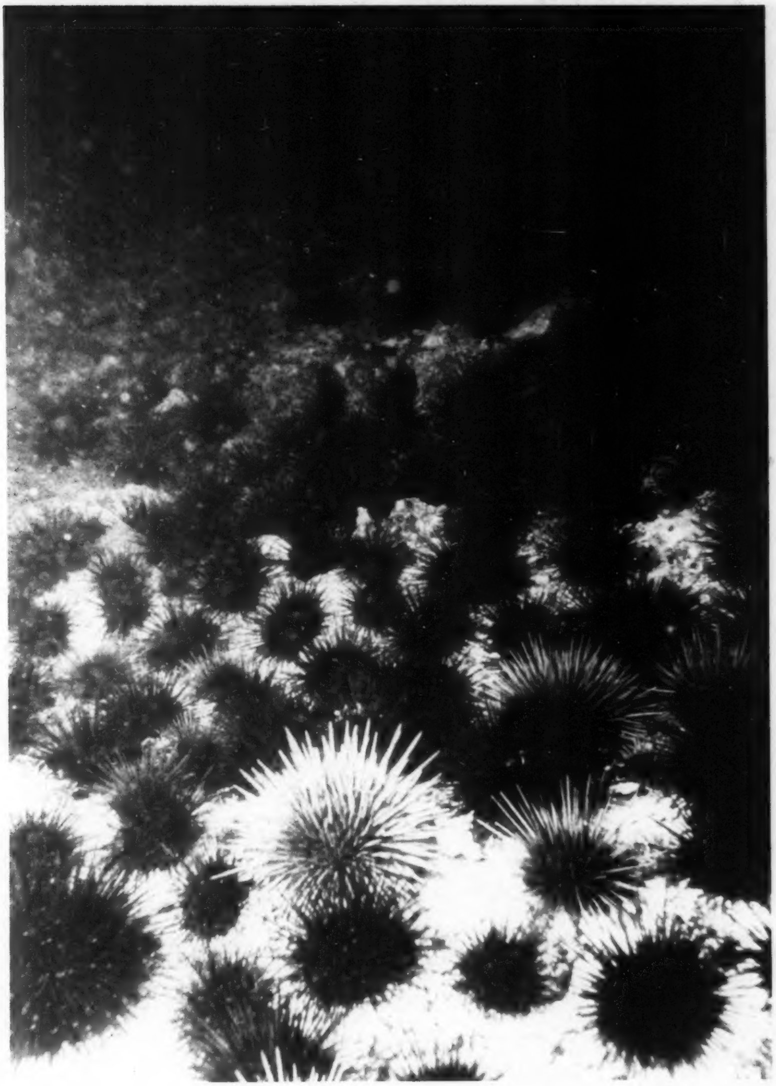
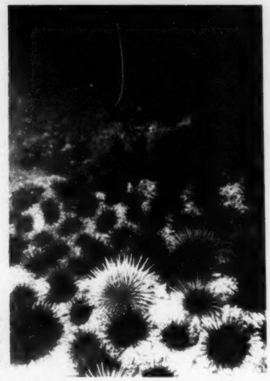


The Red Sea Urchin

Marine Fisheries REVIEW



On the cover: The red sea urchin and the California fishery for it are discussed in the article beginning on page 1.

Articles 47(3), 1985

Biology of the Red Sea Urchin, *Strongylocentrotus franciscanus*, and Its Fishery in California — *Susumu Kato* and *Stephen C. Schroeter* 1

The Columbia River Estuary: An Important Nursery for Dungeness Crabs, *Cancer magister* — *Robert L. Emmett* and *Joseph T. Durkin* 21

Shelf Life Extension of Drawn Whole Atlantic Cod, *Gadus morhua*, and Cod Fillets by Treatment With Potassium Sorbate — *Vincent G. Ampola* and *Cynthia L. Keller* 26

Fatty Acid Composition of Commercial Menhaden, *Brevoortia* spp., Oils, 1982 and 1983 — *Jeanne D. Joseph* 30

Underwater Separation of Juvenile Salmonids by Size — *Michael H. Gessel*, *Winston E. Farr*, and *Clifford W. Long* 38

Relationship of Sea Surface Temperature Isotherm Patterns off Northwestern Mexico to the Catch of Striped Marlin, *Tetrapturus audax*, off Southern California — *James L. Squire, Jr.* 43

Recreational Albacore, *Thunnus alalunga*, Fishery by U.S. West Coast Commercial Passenger Fishing Vessels — *Dave Holts* 48

Charterboat Catch and Effort from Southeastern U.S. Waters, 1983 — *Harold A. Brusher* and *Barbara J. Palko* 54

Departments

NOAA/NMFS Developments 67

Foreign Fishery Developments 72

Publications 84

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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Biology of the Red Sea Urchin, *Strongylocentrotus franciscanus*, and Its Fishery in California

SUSUMU KATO and STEPHEN C. SCHROETER

Introduction

Since Kato (1972) reported on the beginning of the sea urchin fishery in California, it has grown dramatically. The catch has exceeded 11,000 metric tons (t) in 1981 in California, and up to 500 t have been harvested in 1 year in Washington. Most of the product of the fishery, the roe (both male and female gonads), is marketed in Japan, where the sea urchins as well as the roe are called "uni."

Inevitably, development of the fishery has raised questions about the status of populations, and effects of the fishery on the urchins and environment. Because fishermen, processors, potential investors, and management officials all require information, several scientific studies were initiated by researchers in Canada and the United States to answer some of these needs. This report presents relevant information from the literature, much of which is not readily accessible to persons in the industry, as well as from our own investigations. A review of red sea urchin, *Strongylocentrotus franciscanus* (Fig. 1), biology is given to promote understanding of natural processes which can have a bearing on the commercial use of sea urchins. Descriptions of the harvesting, processing, and marketing sectors of the industry are also presented. We hope that this information will aid in maintaining a commercially viable and environmentally sound fishery for many years. We hope that this report will fill the needs of the hundreds of persons from throughout the United States as well as other countries who have requested information to help them develop fisheries for their species of sea urchins.

Description of Sea Urchins

Sea urchins belong to the phylum Echinodermata, which also includes starfish, sea cucumbers, sea lilies, and brittle stars. All sea urchins have a hard calcareous shell called a test, which is covered with a thin epithelium and is usually armed with spines. The mouth, located on the underside, consists of five calcareous plates called "Aristotle's lantern" in honor of the Greek naturalist and philosopher. The mouth leads to the digestive tract which empties through the anus located on the top of the test.

Five skeins of roe comprise the most prominent structures in the internal cavity of sea urchins. Sea urchins are

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ABSTRACT—The California fishery for the red sea urchin, Strongylocentrotus franciscanus, *has grown steadily since its inception in 1972, and the maximum annual catch has exceeded 11,000 metric tons. Most of the product of the fishery, the roe, is exported to Japan, though a significant amount is also consumed in the United States. This paper describes aspects of red sea urchin life history, distribution, abundance, ecology, and management. A detailed description of the fishery, including harvesting, processing, shipping, and marketing methods, is also given.*

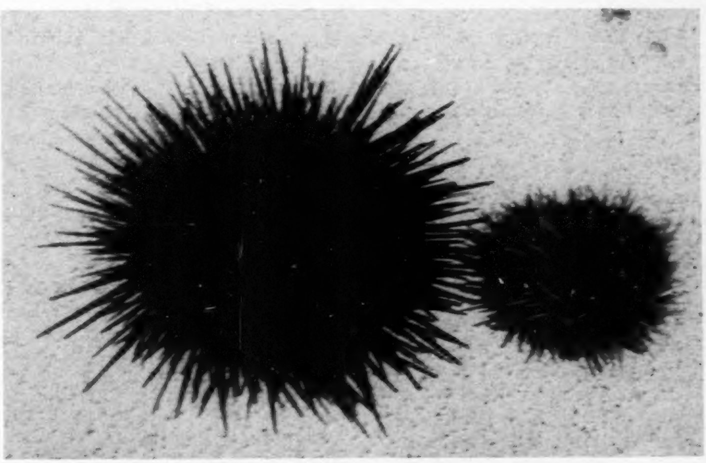

Figure 1.—The red sea urchin, *Strongylocentrotus franciscanus* (left), and the smaller purple sea urchin, *S. purpuratus*.

unisexual, being either male or female, but cases of hermaphroditism (i.e., with both male and female gonads) have been recorded in several species (Boolootian and Moore, 1956). Between the skeins of roe are gill-like structures which are part of the water vascular system, important in movement, respiration, and food gathering. The gut is dark and often filled with partially digested plant material.

Two species of sea urchins are common in shallow coastal waters off California: The red, *S. franciscanus*, and purple, *S. purpuratus*, sea urchins (Fig. 1). Several other species also occur in California, but they are either too small or too rare to be of economic significance. In fact, only the red sea urchin is presently harvested, although the purple sea urchin offers potential because of its abundance. The red sea urchin is one of the largest species of sea urchins in the world, growing to a test diameter of about 18 cm. Its test and spine color is usually dark purple. Not infrequently, however, either the test or spines—or both—are reddish or light purple. The length of the spines may be correlated with the habitat; sea urchins in deeper, calmer waters tend to have longer spines than those in shallower waters where greater abrasion of spines occurs (Silver and Brierton, 1974). The purple sea urchin, which has relatively short spines, is usually light purple or lavender.

Sea urchin roe contains an assortment of nutrients. Major components of the roe of red and purple urchins are given in Table 1. The percentages of various constituents are likely to change, depending on the nutritional and reproductive states of the urchins. Sea urchin roe also contains calcium, phosphorus, iron, Vitamins A, B_1, B_2, B_{12}, nicotinic acid, pantothenic acid, folic acid, and carotenes (Higashi et al. 1959, 1965).

Since polychlorinated biphenols (PCB) and other potentially toxic hydrocarbons are of major concern to the Japanese, an analysis was undertaken to learn the extent of pollution from these noxious compounds. Red sea urchins collected at Fort Bragg, Calif., in 1973 were found to have no detectable amounts of DDT, but contained an average of 0.026 ppm (parts per million of wet weight) of DDE (range 0.006-0.050 ppm). Amounts of PCB averaged 0.04 ppm and ranged from 0.01 to 0.09 ppm[1]. Tolerance levels for PCB set by the Japanese government vary depending on the foodstuff. In flesh of coastal fishes a level of 3.0 ppm is allowed[2]. In the United States, the maximum allowable in "shellfish" is 2 ppm. Thus the California sample fell well within acceptable levels.

Table 1.—Proximate analyses of red and purple sea urchin roe (percent of total roe weight)[1].

	Red sea urchin		Purple sea urchin	
Item	1	2	3	2
Moisture	70.0	70.8	68.6	71.8
Protein	7.7	9.6	9.5	12.3
Lipid	7.6	8.3	5.4	5.2
Ash	1.6	1.5	1.3	1.7
Glycogen	1.3		1.7	
Nonprotein nitrogen	0.1	0.5	0.1	0.5

[1]Sources: 1. Modified after Greenfield et al., 1958; 2. from Kramer and Nordin, 1979; 3. Modified after Giese et al., 1958.

Distribution and Abundance

Red sea urchins are found on the west coast of North America as far south as the tip of Baja California, although their abundance declines south of lat. 27°N (Malagrino Lumare, 1972). They range northward to Sitka and Kodiak, Alaska, and along the Asiatic coast as far south as the southern tip of Hokkaido Island, Japan (McCauley and Carey, 1967). Off the California coast, dense concentrations occur patchily throughout the state. Notable exceptions are those areas off central California where sea otters, *Enhydra lutris*, a major predator of sea urchins, are abundant (McLean, 1962; E. E. Ebert, 1968; Lowry and Pearse, 1973).

Both the red sea urchin and its close relative, the purple sea urchin, usually occupy shallow waters, from the mid to low intertidal zones to depths in excess of 50 m, but red sea urchins have been found as deep as 125 m (McCauley and Carey, 1967). Individuals of both species prefer rocky substrates, particularly ledges and crevices (Schroeter, 1978), and avoid sand and mud.

Both species are often found in and around stands of the giant kelp, *Macrocystis* spp., and other brown algae. Typically, sea urchins are most abundant near the outer edges of kelp beds and less numerous inside (Pearse et al., 1970; Low, 1975; Pace, 1975; Mattison et al., 1977; Tegner and Dayton, 1981). Adult sea urchins that live within kelp beds are larger than those outside, and recent recruits (<10-20 mm) are much more abundant outside than inside the beds (Pearse et al., 1970; Bernard and Miller, 1973; Tegner and Dayton, 1981). Similar patterns have been documented for green sea urchins, *S. drobachiensis*) on the coast of Nova Scotia, Canada (Bernstein et al., 1981). Several hypotheses have been advanced to account for these patterns. Individuals within kelp beds may be larger either because they grow faster, survive longer, or both (Pearse et al., 1970). T. A. Ebert's work (1968) supports the conjecture that individuals inside are larger because they have more food. He studied intertidal populations of purple sea urchins and found that the maximum size attained by individuals in a population is influenced directly by food supply. Additional studies on red sea urchins in southern California (Pearse et al., 1970; Baker, 1973) also support this hypothesis.

The much greater abundance of very small individuals outside of kelp beds may be due to higher rates of settlement, higher survival after settlement, or both (Pearse et al., 1970; Ebert, 1983). Higher rates of settlement could result from active selection by larvae or from the passive concentration of larvae. Alternatively, larvae may be equally abundant inside and outside of beds, but may suffer higher mortality in the former habitat (Pearse et al., 1970).

Juvenile red sea urchins are frequently found under the spines of larger red urchins, and are scarce elsewhere in the same habitat (Low, 1975; Breen et al., 1976; Tegner and Dayton, 1977; Schroeter, 1978). One possible explanation for

[1]Reuben Lasker, National Marine Fisheries Service, NOAA, La Jolla, Calif. Personal commun.
[2]Katsutoshi Miwa, Tokai Regional Fisheries Research Laboratory, Tokyo, Japan. Personal commun.

this distributional pattern is that larvae selectively settle in areas where adults are abundant, and soon find shelter under the larger sea urchins. This hypothesis was tested and rejected by Cameron and Schroeter (1980), who conducted laboratory and field larval selectivity experiments with red and purple sea urchins. They concluded that the pattern of juvenile distribution was due either to increased survival rates under adults, or to migration of young sea urchins under adults following settlement. Hinegardner (1969, 1975) and Cameron and Hinegardner (1974) found that the larvae of white sea urchins, *Lytechinus anamesus*, selectively settle and metamorphose on bacterial films. These films are ubiquitous (Sheer, 1945) and are probably abundant inside as well as outside kelp beds.

An hypothesis that higher mortality of larvae or juveniles inside versus outside kelp beds accounts for patterns of juvenile abundance remains untested; however, the higher abundance of filter-feeding organisms, known to eat sea urchin larvae, inside kelp beds suggests that predation of larvae may be significant (Pearse et al., 1970).

The importance of predation after settlement is suggested by a number of studies which have identified sea urchin predators that are abundant inside or near the edges of kelp beds. These predators include rock crabs, *Cancer* spp. (MacGinitie and MacGinitie, 1968); leather starfish, *Dermasterias imbricata* (Rosenthal and Chess, 1972); sun stars, *Pycnopodia helianthoides* (Tegner and Dayton, 1981); agile sea stars, *Astrometis sertulifera* (Leighton, 1966); bat stars, *Patiria miniata* (Schroeter et al., 1983); and spiny lobsters, *Panulirus interruptus* (Tegner and Dayton, 1981; Tegner and Levin, 1983). Among fishes, the horn shark, *Heterodontus francisci* (Limbaugh[3]) and wolf-eels, *Anarrhichthys ocellatus* (Bernstein et al., 1981), have been observed to feed on sea urchins. In southern California, however, the most significant fish predator is the California sheephead, *Semicossyphus pulcher* (Quast, 1968; Feder et al., 1974; Tegner and Dayton, 1981; Cowen, 1983).

In and near the boundaries of kelp beds, Tegner and Dayton (1977, 1981) and Tegner and Levin (1983) found bimodal size distributions which they attributed to size-specific predation by spiny lobster and California sheephead. Red sea urchins larger than 80 mm in test diameter are less vulnerable to predators because of their size; those smaller than 50 mm take shelter from predators beneath the spines of adults or in cryptic habitats. Because shelter sites are relatively scarce for urchins between 50 and 80 mm (these animals are too large to hide under larger urchins), they suffer high mortality. The mode of larger sea urchins therefore consists of those survivors which accumulate over time. The other mode is made up primarily of small sea urchins <2 years old.

Although bimodal size distribution (with only very small and large sea urchins being represented) can be explained by size-selective predation in areas where spiny lobsters and sheephead are prevalent, studies over many years by the Kelp Habitat Improvement Project[4] have shown that size distribution can vary markedly in different habitats and over time. Local populations in southern California consisted of all small or all large individuals, and any number of combinations of small, medium, and large individuals (State Water Quality Control Board, 1964; Pearse et al., 1970; Anonymous, 1977). Bernard and Miller (1973) also noted varied size distribution patterns for red sea urchins in British Columbia where major predators of small sea urchins are not so prominent. Progressions in size distribution over time in a particular habitat have been well documented by Pearse et al. (1970) and Ebert (1983) who found that food availability and rates of settlement and survival of juveniles were important in determining distribution patterns.

The rate at which existing populations are replenished and the regularity of this recruitment increase from north to south along the west coast of North America. Annual recruitment rates of red sea urchins were lower and often more variable in British Columbia, Canada (Bernard and Miller, 1973; Breen et al., 1978), than in southern California (Mitchell et al., 1969; Pearse et al., 1970; Tegner and Dayton, 1981; Ebert, 1983). The mechanisms underlying such patterns are poorly understood, but latitudinal gradients in temperature, predation, and disease, or interactions of these factors have been hypothesized (Frank, 1975; Fawcett, 1984).

Two other patterns of distribution and abundance are of interest to those engaged in the red sea urchin fishery. The first is clumping, and the second is possible competitive interactions. We've already noted that red sea urchins are often found in high abundance around the edges of kelp beds (Fig. 2). Rosenthal et al. (1974) found that even within kelp beds where adult sea urchins are comparatively rare, individuals occur in aggregations rather than being randomly or uniformly distributed. Low (1975) noted that red sea urchins in British Columbia often occurred in groups or clumps of 50 or more. Smaller groups, as well as solitary sea urchins, tended to merge with the other groups until this apparently critical number was reached. Low (1975) speculated that clumping may be a mechanism to increase the chances of fertilization, to compete with macroalgae for space, or for protection of adults as well as juveniles from predators.

Interspecific competition between abalones, *Haliotis* spp., and sea urchins is known to affect the distribution and well-being of both groups. Abalones seem to outcompete sea urchins for space (Lowry and Pearse, 1973; Shepherd, 1973), although sea urchins may be more efficient in feeding (Tegner, 1980). In southern California, both groups prefer giant kelp, *Macrocystis pyrifera*, to other seaweeds (Leighton, 1966, 1971), so competition for food is likely to occur. Selective fishing for abalones, both in Australia and, in the past, in California, may have contributed to increases in numbers of urchins (Lowry and Pearse, 1973; Shepherd, 1973). Under present condi-

[3]C. Limbaugh, 1959, personal commun. cited by Leighton (1971).

[4]W. K. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Los Angeles, Calif.

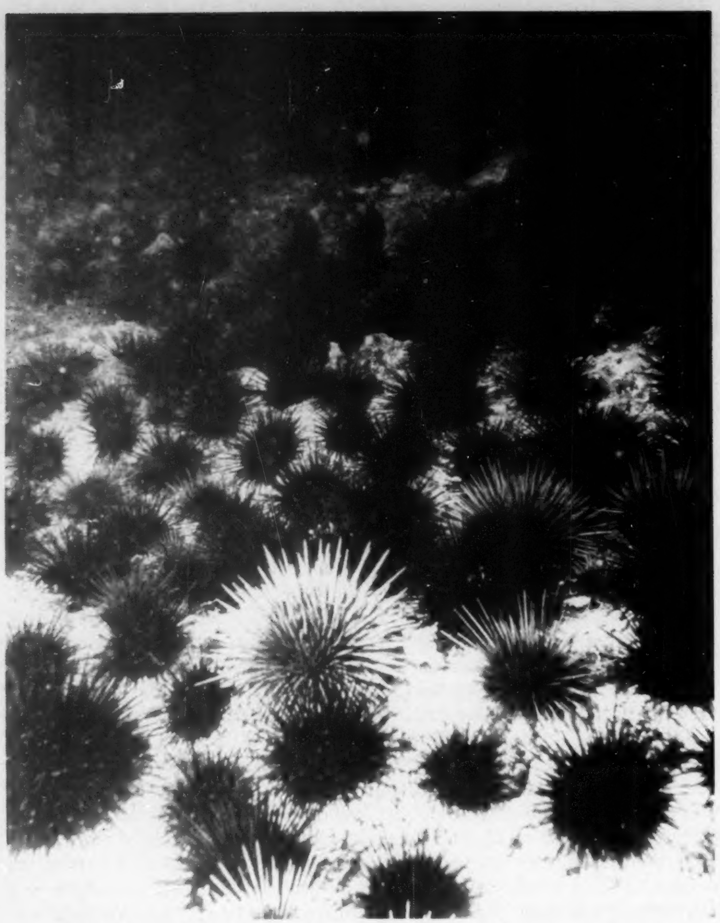

Figure 2.—A group of red sea urchins near kelp beds at Santa Cruz Island, southern California.

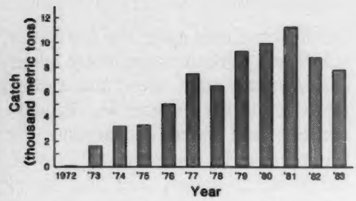

Figure 3.—Annual landings of red sea urchins in California. Source: California Department of Fish and Game.

tions in southern California, however, environmental factors, as well as fishing pressure and predation on sea urchins—rather than on abalones—may be more important than competition in determining distributional patterns and abundance of sea urchins and abalones (Tegner and Levin, 1982).

Schroeter (1978) studied red and purple sea urchins near Santa Barbara, Calif., and at nearby Santa Cruz Island, and concluded that competition for space plays an important role in determining the distribution and abundance of purple sea urchins. The distributions of the two species overlap, but purples dominate in harsh habitats (e.g., mid-intertidal and intertidal, as well as subtidal habitats exposed to waves and surge) while reds dominate in benign habitats (sheltered habitats in the low intertidal and subtidal areas). Purples are more abundant than reds in the harsher habitats because they are more tolerant of physiological stress and wave and surge action. Although purples actually prefer benign to harsh habitats, reds outcompete them there and so reduce their abundance. Because the two species compete, the selective removal of reds by the sea urchin fishery may cause an increase in the abundance of purples in the subtidal habitat. This in fact happened following small-scale experimental removals of reds in the shallow subtidal zone.

Any discussion of sea urchin distribution would be incomplete without inclusion of the effects of predation on sea urchins by sea otters, *Enhydra lutris*. Once almost extinct in California, sea otters now inhabit much of the central California coast, and it is not coincidental that sea urchins are scarce wherever sea otters are present. Sea urchins are among the most common food items of sea otters, and those sea urchins remaining in subtidal waters where otters are present are usually found deep in crevices (McLean, 1962; North, 1965; Leighton, 1966; E. E. Ebert, 1968; Lowry and Pearse, 1973).

No data are available on the abundance of red sea urchins along the California coast, but annual catch totals (Fig. 3) give some measure of harvestable populations. At first glance it would appear that the California fishery reached its harvest potential in 1981, when 11,300 t were landed. The lower catches in 1982 and 1983 may not have been directly related to abundance of sea urchins, however, and the declining catch may not signify that the maximum catch has been attained.

A major climatological event, commonly called "El Niño," occurred in 1982, affecting fisheries throughout the west coast, and indeed the whole Pacific Ocean. Unusually warm water invaded the southern California coast and weak-

ened or killed kelp, the major food of sea urchins. Later in the year, severe storms associated with El Niño finished the job by tearing the weakened kelp from the seafloor[5]. The same storms made it impossible for divers to work in the winter and spring of 1982-83. Too, during much of 1983 the roe yield of red sea urchins was lower than normal, often to the point of making processing uneconomical[6]. The small gonads might also be linked to lower feeding activity. For red sea urchins, feeding rate is greatest at 16°C. The rate declines as the temperature increases (Leighton, 1971). During most of 1982-83 bottom temperatures were significantly above 16°C in red sea urchin habitats (Shelton et al., 1982). Several processors had to close their plants, while others continued operating at lower production levels. Thus, whether or not the southern California populations are presently being fished to their maximum potential is open to question. However, northern California fishing grounds have certainly not been worked to any extent, and expansion of the fishery is likely to occur there when conditions warrant.

Movements and Aggregating Behavior

Patterns of movement and aggregation of red sea urchins are important to fishermen and resource managers, as moving hordes of sea urchins can sometimes decimate large fields of algae (Leighton et al., 1966; Leighton, 1971; Dean et al., 1984). In many cases, however, red sea urchin populations are stationary and highly aggregated where food is abundant; they are less aggregated and move more when food is scarce (Vadas, 1968; Pace, 1975; Russo, 1979; Harrold and Reed, In press). Mattison et al. (1977) found such a pattern and documented differences in rates of movement. Movement of red sea urchins inside a kelp bed where food was abundant averaged about 7.5 cm per day. In comparison, in areas some distance from the kelp bed (15-100 m away) where food was relatively scarce, movement averaged over 50 cm per day. Experimental studies by Lees (1970) in Mission Bay in San Diego, Calif., also showed that food scarcity stimulates the movement of both red and purple sea urchins. On the other hand, Silver and Brierton (1974) found no mixing between two groups of red sea urchins which were located close together in depths of 3 and 11 m, separated by a nearly vertical rock face. The shallow group had an abundant supply of kelp, while the deeper group lived in an area with much less food and devoid of attached kelp.

Reproduction

Knowledge of sea urchin reproductive biology is valuable to those conducting the fishery; the yield of roe is greatest just before spawning when it may reach 20 percent of the total body weight. However, during the peak of reproductive activity, uptake of water by the gonads causes them to exude a great deal of gonadal material (Miller and Mann, 1973), and the roe has low marketability. Thus, the best quality roe is found just before the onset of proliferation of sex cells and before the mature gonads absorb water. After spawning, the gonads are small and the yield is too low for economic use, being 50 percent or less of the peak yield (Kramer and Nordin, 1975).

Increase in gonad size is actually related to feeding, rather than to some intrinsic reproductive cycle, and to storage of glycogen (a carbohydrate) in the gonads (Giese et al., 1958). Bernard (1977) explained the somewhat complicated processes that occur during the development of mature gametes, and concluded that food availability is the key to synchronization of the reproductive cycle in red sea urchins. The reproductive events of sea urchins follow a more or less annual cycle, but there are significant and interesting variations in the pattern.

The spawning season of red sea urchins appears to vary depending on locality and sometimes even from year to year at the same place. In various coastal localities from Papalote Bay, Mexico (near central Baja California), to Whites Point, Calif. (near Los Angeles), Pearse et al. (1970) found indications of spawning between June and November. Most of the populations showed no large increases in gonad size prior to spawning, and the gonad weight was usually less than 10 percent of the body weight. In these populations the gonads underwent a sharp decrease in weight during some time of the year, however, indicating that the populations had spawned. An exception was the population at Point Loma, in San Diego, Calif., which maintained large gonads throughout the year (March 1969-March 1970) and failed to show the marked decrease in gonad size which accompanies spawning. This population was thought to spawn throughout the year. The Point Loma population was the only one of those studied that existed in an area with abundant food.

Baker (1973) also studied red sea urchins at Point Loma in 1972-73 and found a similar lack of a well-defined period in which the decreased gonad weight indicated spawning. On the other hand, he found a lower gonad weight during summer in populations inhabiting nearby Mission Bay. Evidently the populations at the two areas were in different physiological condition; gonads of Point Loma sea urchins averaged 11.58-15.71 percent of the total weight of the sea urchin throughout the year, while those from Mission Bay sea urchins averaged 8.60-10.75 percent. Bennett and Giese (1955) found a late spring-early summer spawning season in central California; workers in Canada detected possible spawning periods from spring to fall (Bernard and Miller, 1973; Kramer and Nordin, 1975, 1979; Bernard, 1977).

A measurement commonly used to estimate a sea urchin's reproductive state on a gross (nonmicroscopic) level is the "gonad index." The index, a relative measure of gonad size, is simply the ratio (expressed as a percentage) of the gonad weight or volume to the total weight or volume of the sea urchin. An abrupt loss of gonadal bulk evidenced by a decline in the gonad index indicates that spawning has taken place.

To determine the reproductive condition of red sea urchins harvested by the

[5]Ron McPeak, Kelco Co., San Diego, Calif. Personal commun.
[6]Neal Matsushita, S/M Uni Co., Los Angeles, Calif. Personal commun.

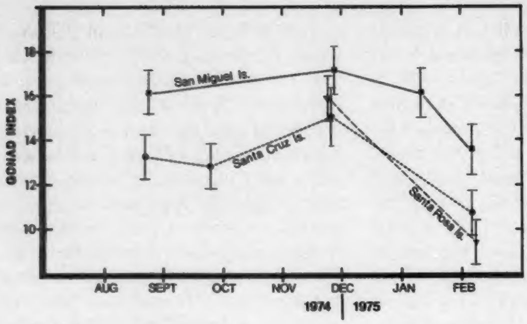

Figure 4.—Means and standard error for gonad indices of commercially caught red sea urchins (percent gonad weight of total weight of drained sea urchins).

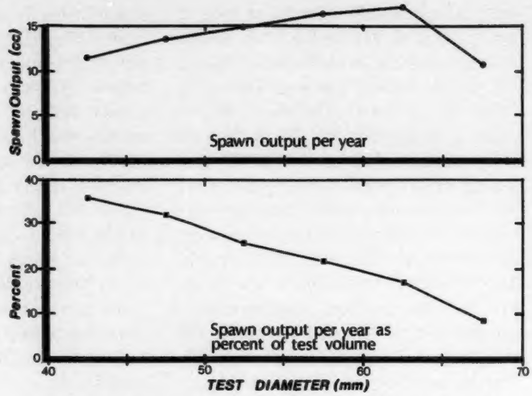

Figure 5.—Spawn output related to test diameter for the white sea urchin, *Lytechinus variegatus* (after Moore et al., 1963).

fishery, we calculated gonad indices (100 × gonad weight ÷ drained body weight) of red sea urchins harvested in 1974-75 by commercial divers from the northern Channel Islands (Santa Cruz, Santa Rosa, and San Miguel Islands). When these samples were taken, spawning was fairly synchronous among the different sites. The gonad indices were high from August to December, but they dropped from December to February (Fig. 4), thus indicating spawning during the latter period.

It should be noted that our samples were not representative of the whole population because spawned-out animals are usually not collected by divers; thus, on the whole, harvested sea urchins are likely to have a higher gonad index than the general population. Even with this bias toward higher indices, the results clearly indicate a discrete spawning period lasting at least from December through January. Red sea urchins that we sampled from commercial landings in 1976 in northern California (Fort Bragg) (unpubl. data) also indicated a winter-to-spring spawning period.

The maximum gonad size attained differs not only from locality to locality (Leighton, 1967; Pearse et al, 1970; present study, Fig. 4), but also from year to year at the same locality (Bennett and Giese, 1955). The causes of this variability have yet to be determined, but according to several sea urchin divers, differences in food supply may be most important. Divers often report that sea urchins near lush algal stands have much larger gonads than individuals located several meters away where algae are scarce or absent. Others have also noted the importance of food to the growth of gonads, which are not only reproductive organs, but also sites for food storage (Giese et al., 1958; Bernard, 1977; Dean et al., 1984).

The amount of gametes produced (usually measured by size of gonads) may not be directly correlated with size or age of the urchins. Bernard and Miller (1973) indicated that red sea urchins in British Columbia probably first spawn at age 2 at around 50 mm test diameter. We were able to induce spawning in red sea urchins as small as 40 mm at Santa Cruz Island. The production of gametes by these tiny individuals is, of course, very low.

Bernard (1977) found that the ratio of gonad weight to shell diameter increases with size, until red sea urchins attain 95 mm; the ratio then decreases slightly. Moore et al. (1963) found similar results in their study of the east coast's white sea urchin, *Lytechinus variegatus*. The total spawn output (Fig. 5, above) was greatest for large sea urchins (but not the largest size class), but smaller sea urchins were relatively more productive when spawn output was expressed as a percentage of test volume (Fig. 5, below). Thus, to assess the spawning potential of a sea urchin population, one must know the relative abundance of different sized sea urchins, as well as the amount of spawn produced by individuals in the size range.

Another reproductive process important to the sea urchin fishery is the length of time it takes for gonads to regain their bulk after spawning. Data we obtained from a commercial sea urchin processing firm in 1975-76 indicate a rather protracted recovery period lasting from spring to early summer, after the sea urchins had spawned from December through February or March. On the other hand, Bernard (1977) found that in British Columbia the gonad index of red sea urchins returned to 80 percent of maximal levels by October, only 1 month after spawning. The gonads attained their greatest size several months later in May. Kramer and Nordin (1975), however, found an intermediate interval of time between spawning and recovery in their study of British Columbia red sea urchins. The differences may be due to the amount of food available in the respective habitats.

Development and Growth

Development of red sea urchins from fertilization through various free-swim-

ming larval stages to settling of the juvenile takes about 6-8 weeks, depending primarily on water temperature (Johnson, 1930). Depending on a host of environmental and genetic factors, young sea urchins can grow to sexual maturity between 1 and 2 years after they settle on the bottom (Bernard and Miller, 1973; Tegner[7]).

Marks on hard parts have commonly been used to study the age of animals. In sea urchins, rings similar to those found in tree trunks can be seen in the spines, and growth lines or zones also occur in the plates that make up the test. Both have been used to ascertain the age of certain species (Jensen, 1969; Pearse and Pearse, 1975). Detailed studies of the formation of growth zones in the tests of purple sea urchins have disclosed, however, that rings or zones do not necessarily correlate with seasonal phenomena, and are thus not useful for indicating age (Pearse and Pearse, 1975). Breen and Adkins (1976) reported similar negative results for red sea urchins, and our attempts using Jensen's (1969) methods failed to find reliable age indicators in the test plates.

Growth of red sea urchins, measured by increases in test diameter, has been studied in the laboratory (Leighton, 1967, 1971), in cages in the field (Swan, 1961; Schroeter, 1978), and with uncaged field populations (Baker, 1973; Bernard and Miller, 1973). The studies indicated an annual growth increment of 13-25 mm, with smaller individuals showing faster gains in test diameter, as expected. Thus, on the average, red sea urchins probably attain harvestable size (90-100 mm) in around 4-5 years.

Many factors affect growth rates of sea urchins and the maximum size attained by individuals in a local population. These include availability and nutritional value of algae, competition, temperature, and the severity of wave and surge action (Bennett and Giese, 1955; Swan, 1961; Ebert, 1967, 1968; Leighton, 1971; Baker, 1973; Schroeter, 1978).

Food and Feeding

Although red sea urchins feed on many species of algae, they clearly prefer the giant kelp, *Macrocystis* spp., when it is available (Leighton, 1966, 1971). Off the coasts of Washington and British Columbia, red sea urchins prefer the bull kelp, *Nereocystis leutkeana* (Vadas, 1968, 1977).

As one might expect, diets consisting of preferred foods result in much higher growth rates (Leighton, 1971; Vadas, 1968, 1977). A striking demonstration of this phenomenon can be found in southern California, where locally dense populations of red sea urchins eliminated all fleshy algae, forcing individuals to feed on less preferred and nutritionally inferior encrusting coralline algae (e.g., *Lithothamnion* spp. and *Bosiella* spp.). Sea urchins in such areas typically have only the rudiments of gonads and appear to be starved (State Water Quality Control Board, 1964).

Plankton, as well as organic suspensions produced by sewage outfalls, are also utilized by sea urchins. In fact, the latter source seems to have relatively high nutritional value, and may be the primary factor responsible for persistence of dense sea urchin populations even after they have overgrazed and eliminated their normal algal food source (Pearse et al., 1970). Finally, when food is scarce or absent, sea urchins can derive energy necessary for maintenance by resorbing their gonadal and gut tissues.

Feeding rates of red sea urchins are influenced by temperature. The optimum feeding temperature is about 16°C, and red sea urchins feed as long as the temperature remains between 6° and 25°C. In southern California, at depths where red sea urchins are most abundant, bottom temperatures are generally higher and nearer the 16°C optimum in winter than in the summer (Leighton, 1971).

Ecology and Management

As noted above, grazing by red sea urchins has a profound influence on the types of algae that ultimately dominate a particular habitat. This is because sea urchins prefer to eat certain species, thereby leading to the dominance of the less preferred species. In some cases, the less preferred species are poor competitors, and owe their persistence in the community to the grazing activity of sea urchins. Experimental removal of sea urchins often results in local competitive elimination of the less preferred species of algae (Vadas, 1968; Paine and Vadas, 1969; Palmisano, 1975; Pearse and Hines, 1979; Duggins, 1980).

The influence of sea urchin grazing on giant kelp in southern California has received a great deal of attention, since sea urchins have been held responsible for the widespread disappearance of this economically and environmentally valuable species (North and Pearse, 1970; Leighton, 1971; North, 1974). Researchers from the California Department of Fish and Game, Scripps Institution of Oceanography, California Institute of Technology, and Kelco[8] (a commercial kelp harvesting firm), and groups of recreational divers have worked on the restoration of kelp beds for over 20 years. Almost without exception, attempts to restore kelp forests have started with the eradication of sea urchins, and successful results of some of these efforts seem to demonstrate that sea urchin grazing is a principal reason for failure of giant kelp to become reestablished in certain habitats (North, 1974). Of course, other factors such as competing vegetation, other grazers, and adverse environmental conditions also act to hold down kelp growth (Wilson et al., 1978).

In areas where the standing crop of algae is well established, sea urchin presence is not necessarily detrimental to the plant community (Rosenthal et al., 1974), and removal of large numbers of sea urchins may not affect the algal abundance or distribution (Breen et al., 1978).

From the point of view of those favoring kelp propagation, it is clear that reduction in numbers of red sea urchins would be beneficial. Indeed it has even been suggested that sea otters be reintroduced into southern California for this purpose. It would seem, however, that the commercial fishery is a more satisfying means of controlling growth

[7]Scripps Institution of Oceanography, La Jolla, Calif. Personal commun.

[8]Mention of trade name or commercial firms does not imply endorsement by the authors or by the National Marine Fisheries Service, NOAA.

in populations of red sea urchins, which are valuable renewable natural resources. The fishery brings income to the industry as well as helping in some measure to lower our deficit in the balance of trade of seafood products. On the other hand, selective removal of red sea urchins may allow growth in the population of purple sea urchins, which can also cause overgrazing when large numbers are present. These two species overlap to a great degree (except at the shallow end of the range), and their food preferences are similar.

To maintain a long-term fishery, some management measures may need to be instituted, for it is clear from studies by Canadian researchers that recovery of exploited red sea urchin populations is a slow process (Breen et al., 1978). In the absence of regulations, divers should take it upon themselves to ensure that enough large sea urchins are left in harvest areas to support recruitment of young urchins, which need the protection afforded by the spines of larger individuals. Perhaps a maximum size limit would help in this regard.

Most persons involved in the California fishery feel that management is called for to prevent damage to sea urchin stocks. One management option favored by many divers, according to two polls, is a limit on the number of persons allowed to fish for sea urchins[9]. Some processors we interviewed also felt that economic returns should be considered in any management scheme. For example, they advocate closure of the fishery during spawning season when the roe is soft and unappealing, and until the gonads recover to near maximum bulk.

Since the precise time of spawning may vary from year to year and at different locations, however, it would be unwise to set prescribed open and closed seasons. Obviously, divers and processors have the best and earliest knowledge of these events when they occur, and it behooves them to work together to stop fishing in areas where gonad quality and quantity are low. Another period of marginal profitability is during spring and early summer when the roe yield is still rather low, as are the prices in Japan. However, market conditions do vary, and in some years it has been profitable to export roe even in summer.

Not all processors and fishermen advocate long seasonal closures of the fishery. They point to the difficulty of keeping key personnel during the off-season, or counting on their return when processing resumes, and also to the fact that some good sea urchins can be found throughout the year. Those firms that supply the domestic market especially need to operate throughout the year or chance the loss of their markets to imports.

The State of Washington has a rather simple management system, whereby the coast is divided into three zones, one of which is closed to sea urchin fishing each year to foster repopulation[10]. In Japan, seasonal, depth, and gear restrictions are all used to help ensure against overfishing, and habitat improvement programs are also employed to encourage settlement and growth of sea urchins (Mottet, 1976).

In the absence of State-mandated fishery regulations, members of the California industry might well impose self-regulatory measures to ensure the future of the fishery. The collapse of the sea urchin fishery in northwest France in the 1960's (Southward and Southward, 1975) should serve as amble reminder to all that sea urchins are susceptible to overfishing, and the authors pointed out that sea urchins are important for maintaining a balance in the ecosystem. They plead: "The lowly sea urchin is strongly in need of friends to come to its rescue."

History of the Fishery

In the 1960's, a few individuals harvested small numbers of sea urchins for home consumption and for the domestic market in California. With increasing numbers of Japanese restaurants opening in the United States to serve the growing Japanese business communities in the financial centers—New York, Chicago, Los Angeles, San Francisco—the demand for exotic (at least to conventional American tastes) fish products increased. Much of the fare served in these restaurants was traditional Japanese, including raw fish and shellfish, fish eggs (including uni, or sea urchin roe), eels, jellyfish, and the like. Since many of these were not readily available in the United States, they were imported from Japan. And, owing to the high cost of air freight, most of these items were transported by ship in the frozen state which, although unacceptable in Japan, was the only form available in the United States.

In 1968, the NMFS Southwest Fisheries Center started looking into the feasibility of developing a sea urchin fishery to supply the growing domestic markets and for export to Japan. The decision to try to initiate a fishery was prompted not only by the demand for the product, but also because sea urchins were considered pests by kelp harvesters, recreational fishermen, and the abalone industry. In fact, groups of sport divers regularly held organized "urchin kills," whereby divers armed with hammers would smash any and all sea urchins found in selected habitats. Quicklime (calcium oxide) was also used to control sea urchins in commercial kelp beds. Now, however, state regulations prohibit the use of quicklime because of strong objections by sea urchin divers and other fishermen.

Since the processing of sea urchins requires a large number of low-skilled workers, a new fishery also offered increased employment opportunities for such workers. Other advantages of a sea urchin fishery included reduction in fishing pressure on abalone, possible improvement in the habitat for abalone and other invertebrates and fishes that depend on seaweed for shelter or food, and lowered deficit in the U.S. international seafood trade.

In the early phases of development in 1972, we sent trial shipments of frozen roe to Japan, the principal market. Because the defrosted roe became soft and unappealing due to cell rupture, no interest was shown by the Japanese market for the frozen product. Since the prevail-

[9]David Parker, California Department of Fish and Game, Long Beach, Calif. Personal commun.

[10]Richard Burge, Washington Department of Fisheries, Shellfish Laboratory, Brinnon, Wash. Personal commun.

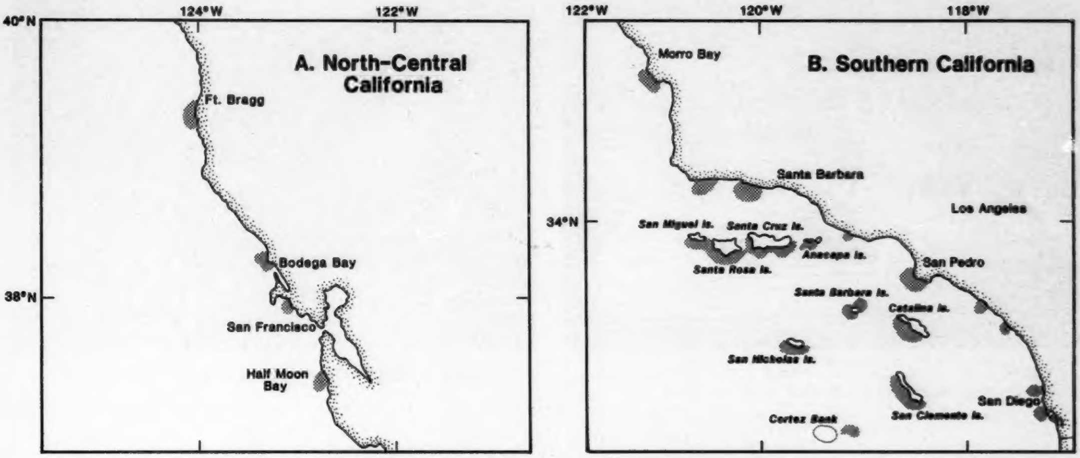

Figure 6.—Major California fishing grounds (shaded) for red sea urchins.

ing monetary climate prohibited air freight of fresh roe to Japan, we decided to concentrate on supplying the domestic market while experimenting with means of preserving the roe in better condition. First, we had to experiment with processing methods since we were unable to find descriptions in the literature. Time and motion studies and cost analyses were carried out in a pilot operation at Avila Beach, Calif., to determine if the business had potential profitability. All studies indicated good potential, especially if initial investment was low (Kato, 1972). In 1972 a trip to Japan by the senior author provided detailed information on the processing and marketing of sea urchin roe and contacts with potential buyers. This new information, and the right monetary conditions (the Japanese yen had just been raised in value relative to the dollar by 25 percent), convinced a Los Angeles processor to open the first major sea urchin processing plant in late 1972. A technician from Japan was hired by the firm to provide processing expertise in handling fresh roe, and the industry was underway.

Since its inception in 1972, the fishery has grown steadily to become one of the leading fisheries in California. Annual landings increased to 11,000 t in 1981, but declined somewhat in the next 2 years. The following sections describe the harvesting, processing, and marketing sectors of the California sea urchin fishery.

Harvesting

The bulk of the California sea urchin catch comes from the northern Channel Islands (Fig. 6) off the southern California coast. Anacapa and Santa Cruz Islands were formerly the areas of highest production, but presently San Miguel, Santa Rosa, San Nicolas, and Santa Barbara Islands produce most of the catch. Divers are forced to seek new localities as sea urchin density becomes too low for economic harvesting, or when the quality and quantity of roe fall below acceptable levels. Santa Catalina and San Clemente Islands, as well as Cortez Bank, have also provided some sea urchins, as have many localities along the mainland coast from San Diego to Fort Bragg. The relative amounts landed in various regions in California are shown in Table 2. The fishery now appears to be harvesting those sea urchins that have reached marketable size in areas previously exploited.

Table 2.—Annual California landing of sea urchin by district (percent of total landings).

Year	Eureka[1]	San Francisco	Monterey	Santa Barbara	San Pedro	San Diego
1973	<1	<1	<1	96	4	<1
1974	<1	<1	<1	97	1	1
1975	<1	<1	<1	95	3	2
1976	<1	<1	<1	94	1.3	4
1977	2	<1	<1	78	10	9
1978	<1	<1	<1	70	19	11
1979	1	<1	<1	76	18	5
1980[2]						
1981	<1	<1	<1	71	16	12
1982	<1	<1	<1	74	15	10
1983	<1	<1	<1	72	18	10

[1]Most of these landings were made at Fort Bragg and Albion.
[2]Statistics for 1980 were not available.

Vessels and diving gear in the sea urchin fishery are similar to those used by the abalone fishery. All harvesting is done by divers using conventional "hookah" gear, i.e., a low-pressure air compressor connected to a reservoir which feeds air through a hose to a faceplate. The compressor is usually rated at 80-125 p.s.i., and most can accomodate up to three divers. Divers wear 6-10 mm thick rubber "wet suits" or thinner "dry suits" to ward off the cold.

The most popular diving boats are

Figure 7.—A 9.1 m (30 foot) Wilson drive boat; note the two large mesh bags full of sea urchins.

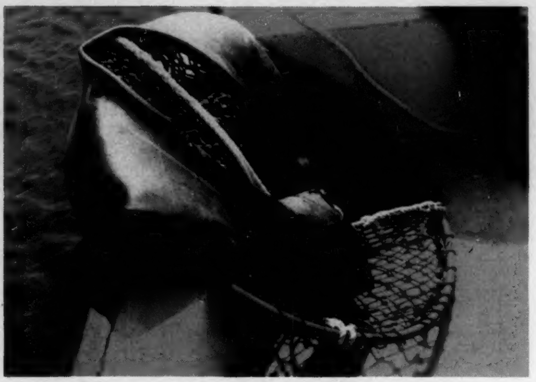

Figure 8.—Sea urchin collecting bag with rubber tube.

made by Radon and Wilson (Fig. 7). The vessels are made of fiberglass, usually around 8-9 m long, and powered with diesel engines. The carrying capacity is 1.5-3 tons. The chief criterion, besides adequate carrying capacity, appears to be speed, which is important because some of the fishing grounds are a considerable distance from port. Most sea urchin boats can cruise at 15-20 knots. In the past, vessels with large capacity, such as albacore trollers, were used as carriers for transporting sea urchins from the fishing grounds to dockside. Some divers operate by themselves, while those in larger vessels usually work in pairs or threes. All the divers on a boat may be in the water at the sime time, or one may act as a tender, loading the catch into the boat. Major home ports of the sea urchin diving boats are Santa Barbara, Oxnard, Port Hueneme, and San Pedro.

Diving operations begin with preliminary searches for concentrations of sea urchins. After finding an area with adequate numbers, the diver cracks open a few sea urchins to check the quality of roe. If satisfactory, harvesting begins. Most divers have their own methods for collecting sea urchins. One effective method is to use a short-handled rake to dislodge sea urchins and scoop them into a small collecting bag or wire cage. As this is filled, the sea urchins are transferred underwater into a larger mesh bag, about 2 m long, with a 1.4 m ring opening (Fig. 8).

After the first batch of sea urchins is transferred, air is pumped from the breathing apparatus into a rubber tube attached to the ring. This causes the ring to rise, and the bag is maintained at a convenient height, anchored by the weight of the sea urchins. As the bag is filled with more sea urchins, additional air is put into the tube to increase the height of the bag. When the collecting bag is completely filled with 50-70 kg of sea urchins, the tube is filled with enough air to float the bag to the surface. A line attached to the boat keeps the bag from drifting away[11]. This method is especially useful for single-diver operations. Boats with tenders (or diver-tenders) often store collected sea urchins in large cargo nets, which facilitates unloading (Fig. 9).

All harvesting is currently done by hand, although an airlift system was tested by one firm, with reported success. In our own experiments, we successfully pumped red sea urchins through a 25 cm hose from depths of 15 m, but we found it difficult to get enough force with an airlift system at shallower depths. Further, we found the hose too cumbersome and impractical to use in areas of dense kelp.

[11]Jerome Betts, commercial sea urchin diver, Lompoc, Calif. Personal commun.

Because of the hard physical labor, cold water, and pressure, divers are forced to surface often to rest, and actual diving time is restricted to a few hours (usually 3-4) per day. Weather conditions and other factors further limit a diver's fishing time to around 80 days per year. Although most divers make daily fishing trips, some with large vessels make 2-day trips. On these occasions, collected sea urchins are kept in mesh bags underwater in sheltered spots until the trip home.

Divers were interviewed periodically between July 1974 and February 1975, and again in January and February 1977 to get catch data. These divers fished at the Channel Islands and at mainland sites just north of Santa Barbara. Data thus obtained revealed that catch rates did not change significantly during the two periods (Table 3). Boats with a single diver averaged around 250 kg/hour during both periods, and diving

Table 3.—Comparison of catch per day by single-diver boats during two periods.

Item	July 1974-Aug. 1975 N = 38	Jan.-Feb. 1977 N =12
Average catch per day (kg)	918	922
Average time spent underwater (hours)	3.4	3.7
Average catch per hour underwater (kg/hour)	269	249

time averaged about 3.5 hours per day. Data from 48 deliveries made by single-diver boats (including the 38 in Table 3) and 16 deliveries by two-diver boats showed that the latter were somewhat more productive. The single-diver boats averaged 986 kg/day while the two-diver boats averaged 2,258 kg/d (or 1,129 kg/diver). In 1983 the average catch for single-diver boats was lower, probably on the order of 780-900 kg/day[11]. In some areas, such as near San Diego, the daily catch is usually even lower.

The average depth fished during 1974-75 was 8.2 m (range 4.0-15.2 m). Most divers interviewed recently reported diving a bit deeper on the average.

The number of boats engaged in the fishery varies considerably by year. During the peak year of 1981, 271 boats reported sea urchin landings. Of these, 42 boats (15 percent) landed 56 percent of the total catch, and 85 boats landed 85 percent[9].

In port the catch is weighed and loaded directly into waiting trucks which haul the sea urchins to processing plants. The unloading booms are usually equipped with scales to weigh the catch. Some divers sell their catch through a "middleman" who handles unloading and transport, as well as market orders and dispatching boats.

The average size of red sea urchins changes with harvesting intensity, becoming progressively smaller with time. At times, however, the size increases (Fig. 10, Santa Rosa and Santa Cruz) rather than declining. This can probably be explained by the movement of divers into deeper waters as the number of large sea urchins decreases in shallower depths. Thus, a longer sampling period would probably have shown a second decrease in the size of the sea urchins harvested from the same area, as indicated by the San Miguel Island sea urchins (Fig. 10).

The mean test diameter of red sea urchins sampled from the commercial landings at Santa Barbara from July 1974 to February 1975 was 108 mm (95 percent measured 102-114 mm and 99 percent measured 100-116 mm). Recently, however, the average size has been considerably lower; the diameter of 27 red sea urchins measured at a processing plant in October 1983 averaged 87 mm. All processors interviewed at that time agree that the size has decreased considerably.

Those wishing to harvest sea urchins in California must obtain a commercial fishing license ($40). A revocable sea urchin fishing permit is also now required under a State law enacted in 1984. All vessels used in commercial fishing operations require a certificate of boat registration ($125). These fees are assessed each license year (1 April-31 March).

Figure 9.—Sea urchins retained in cargo nets on dive boats are easily and quickly unloaded into trucks.

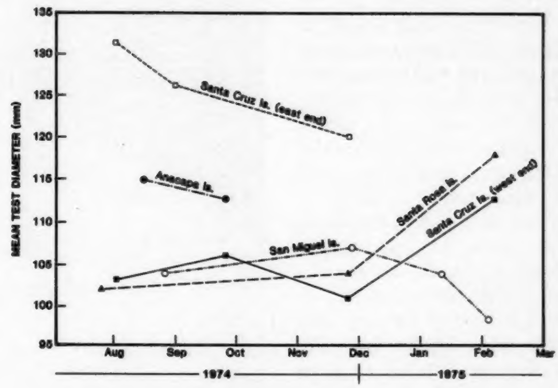

Figure 10.—Mean test diameter of red sea urchins taken by the commercial fishery at the northern Channel Islands in 1974-75.

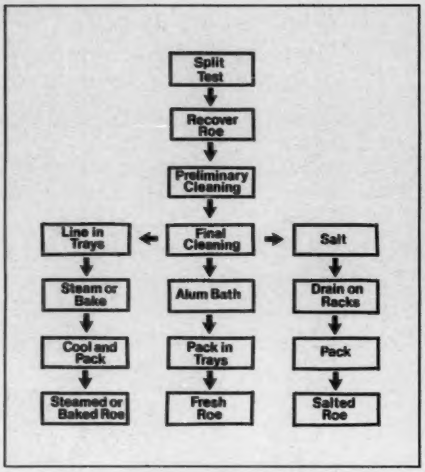

Figure 11.—Flow diagram of sea urchin processing steps. Frozen roe is treated similarly to fresh roe.

Figure 12.—Some tools of the trade: Stackable plastic strainer for cleaning roe, metal shell-cracking device, wood tray for packing roe.

Processing

Sea urchin processing has not changed appreciably since the earlier report of Kato (1972). Because the product is now primarily sold fresh rather than frozen, however, packing methods are different, and a chemical treatment is used to improve the appearance of the roe. Only a small amount of roe is salted, steamed, baked, or frozen.

Sea urchins delivered to processing plants in the evening are kept overnight. During warm weather, sea urchins must be stored in refrigerated rooms. Sea urchins kept at 2°C for 1.5 days stay alive, but the roe is noticeably softer and darker (Kramer and Nordin, 1979). Processing consists of several steps which readily lend themselves to an assembly-line operation (Fig. 11). The test is split with a cleaver or a special tool (Fig. 12). The instrument's tip is forcibly inserted into the top of the shell, which is cracked open when the handles are squeezed, forcing the flat blades outward. The roe is removed with a spoon and placed in plastic strainers, then rinsed in cold saltwater to remove viscera and extraneous matter. Final cleaning of attached membranes is done with tweezers or small forks. From this point, processing methods depend on the type of product. The Japanese name is given for each of the products described here.

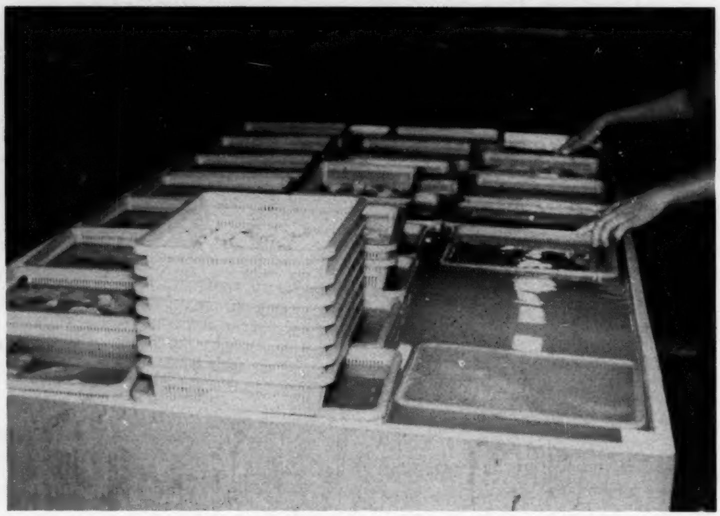

Figure 13.—Sea urchin roe becomes firm when soaked in a saltwater solution containing alum.

1) Fresh roe (uni or nama uni):

A) The roe is placed in stackable plastic strainers.
B) The strainers are placed in tanks containing a solution of anhydrous potassium alum, $KAl(SO_4)_2$, in cold

Figure 14.—Roe is drained thoroughly before packing; a layer of cloth helps absorb moisture.

saltwater until the roe becomes firm (Fig. 13). Concentrations used vary from 0.4-0.7 percent, and soak times vary from 15 minutes to 1 hour.

C) The roe is then drained (Fig. 14) and packed in small wood trays. At least 250 g, and up to 280 g, of roe are packed in a standard tray (Fig. 15). A medium-sized tray containing around 170 g is gaining in popularity, however. Occasionally, smaller trays holding 100, 50, or 30 g are also used. The standard trays measure about 9 cm × 16 cm × 1.3 cm deep (inside

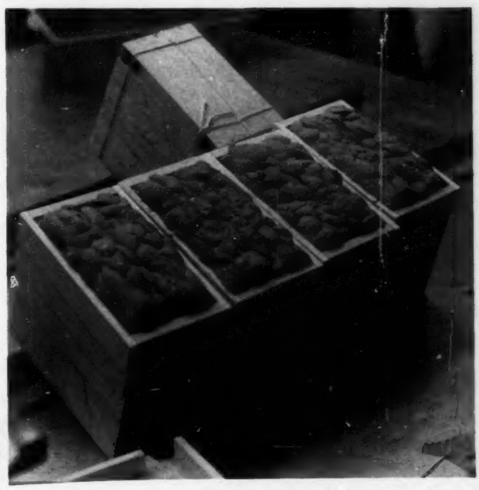

Figure 15.—Wood trays, each packed with around 250 g of red sea urchin roe.

Figure 16.—Roe bulk-packed in foam trays. This roe will probably be used in salted or cooked products.

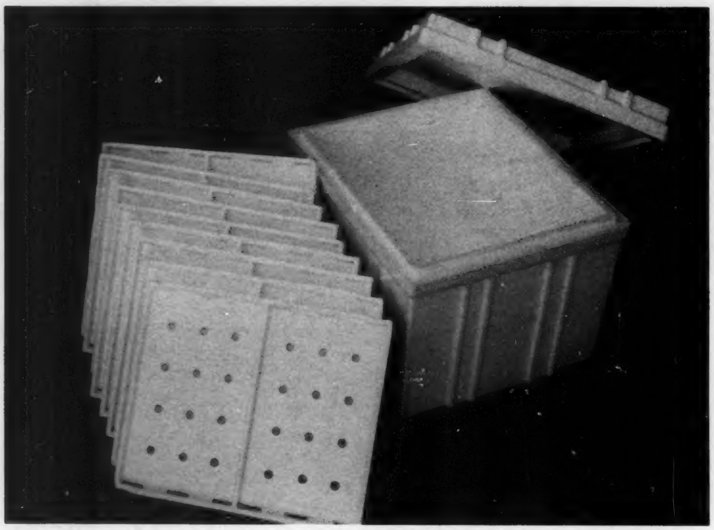

Figure 17.—Insulated master carton used to ship sea urchin roe packed in wood or foam trays. Source of cartons: Plasti Personalities, 1214 W. 252nd St., Harbor City, CA 90710.

dimensions) and cost about $0.30 each.

D) Alternately, the drained roe is bulk-packed in larger perforated foam trays, 32 cm × 40 cm × 2 cm deep (Fig. 16), sometimes lined with absorbent cloth to prevent sliding and damaging of roe in transit. Only one layer of roe is packed in a tray. These trays normally hold about 1 kg of roe.

E) The wood trays are tied in bundles of 8 to 13 trays, with a wooden cover over the top. These are placed in a plastic bag and the roe is allowed to drain further in a refrigerator. It is important that the roe not be exposed to drafts while draining.

F) Just prior to shipment, the trays are placed in insulated master cartons (Fig. 17), each holding 50-54 trays. The bulk-pack foam trays are also stacked and placed in insulated master cartons with about 8-9 trays in each carton. Artificial coolant (commonly called "jelly ice") is added prior to shipment (about 1.4 kg per carton in winter and twice as much in summer).

2) Salted roe (shio uni): Methods of salting vary, depending on the requirements of buyers. Generally, the steps are as follows.

A) Layers of cheesecloth are placed on a wire rack.

B) A layer of roe is placed on the cheesecloth and covered thoroughly with salt; about 25 percent salt to weight of roe is used.

C) More layers of roe and salt are placed on the rack, sometimes with cheesecloth between layers, until the thickness reaches about 5 cm.

D) The roe is allowed to drain for several hours or overnight; about 40-50 percent of moisture is removed, and salt uptake is 10-15 percent.

E) The salted roe is packed in plastic-lined wooden kegs or plastic containers, sometimes with the addition of 10 percent by weight of ethyl alcohol (95 percent).

Recently a new type of shio uni has been produced using less salt but requiring freezing for preservation. This product apparently brings a high price if good quality roe is used[12].

3) Steamed roe (mushi uni):

A) Fresh roe is placed in wood or screen containers of various sizes.

B) The containers are stacked and

[12]K. Yanagita, California Uni Co., Los Angeles, Calif. Personal commun.

Figure 18.—Showcase in a sushi shop. A wood tray filled with red sea urchin roe is seen to the left; two pieces of "uni sushi" are on the counter on the right.

placed in a large steamer.

C) The roe is steamed for about 30 minutes; about 20-30 percent of moisture is removed during the process. Some processors steam roe under pressure, reducing cooking time to 15 minutes or less.

D) The roe is bulk-packed or packed in small wooden or plastic trays, and frozen.

4) Baked roe (yaki uni):

A) Fresh roe is placed in shallow oven-proof dishes.

B) The roe is baked in an oven at 190°C for 30 minutes. About 30-40 percent of moisture is removed in the process.

C) The cooked roe is then packed in small wooden trays (around 30 g) or in plastic imitation "scallop shells" and frozen.

5) Frozen roe (reito uni):

A) Fresh roe of good quality is packed in standard wood trays or bulk plastic trays.

B) The trays are stacked and inserted in a plastic bag, then frozen at −17°C.

C) The frozen roe, still in the plastic bag, is stored in insulated master cartons in the freezer.

This method is used when the product is to be sold later as raw-thawed sea urchin roe, and only good roe is acceptable. If the roe is destined to be salted or processed further, second-grade roe may be used, and it is often simply placed in plastic bags and frozen in bulk.

California firms have experimented with other processing methods in attempts to service specialty markets. Two such items produced were canned roe and freeze-dried roe. In addition, sea urchin roe has been used as feed for aquarium animals, particularly for sea anemones and other invertebrates.

The best quality roe is reserved for the fresh product, which brings the best prices. Secondary products are made from broken roe, or roe that is off-color, too large, or leaking fluids excessively. Salted roe is usually produced in the summer, when the price of fresh roe is low in Japan.

Because appearance is important to the Japanese, who are said to "eat with their eyes," the packing process is critical. In Japan as well as in the United States, most of the roe is bought by "sushi" shops, which are Japanese seafood restaurants specializing in fresh seafood. Customers in sushi shops usually sit at a counter in front of refrigerated showcases which contain many seafoods, mostly raw, in plain view (Fig. 18). Sea urchin roe is displayed in the same wooden trays used by the processor. To maintain good appearance, broken pieces of roe are placed on the bottom, and only whole, firm roe is placed on the top layers of wood trays. The best size is 40-50 mm, but California sea urchin roe is usually larger. Skeins of roe are separated according to their color. Very large skeins are used in other than fresh products, or broken up into smaller pieces and packed on the bottom of trays. Bright yellow roe was historically considered the highest quality in Tokyo, although consumers in different areas of Japan often prefer bright orange roe. Since the late 1970's, orange roe has equalled yellow roe in price in Tokyo.

Trays used for the Japanese market were formerly imported from Japan because only certain types of wood are ac-

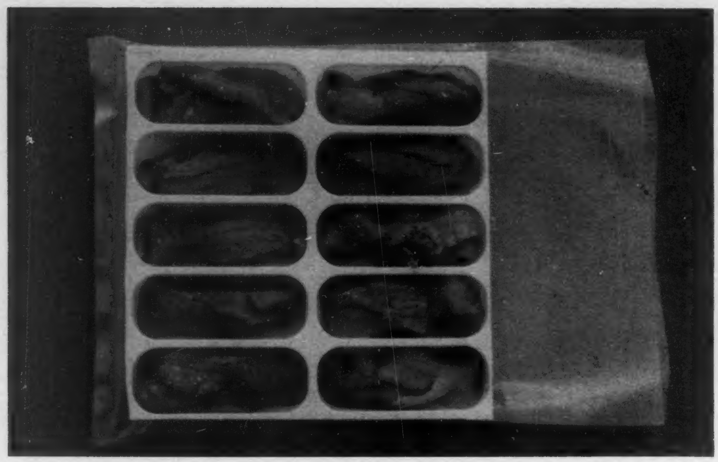

Figure 19.—Sea urchin roe packed for the domestic retail market in an "oyster tray".

ceptable, as they impart some odor or flavor to the roe. Now, however, a firm in Los Angeles manufactures nearly all wood trays used by the U.S. industry[13].

Sanitation is important because sea urchin roe, which is usually sold fresh out of the shell, can easily pick up bacterial and fungal contamination. To counteract bacteria, some processors use ultraviolet-treated water in all phases of processing, and disinfectants are used by all to maintain a sanitary environment. Good refrigeration is also critical, especially during summer.

Labor costs are rather high in an operation which calls for meticulous cleaning, sorting, and packing. Thus several processors turned to bulk-packing methods. In addition to savings in labor costs, bulk-packing also offered lower costs for trays (plastic instead of wood), as well as lower shipping costs, because the plastic trays were considerably lighter, and only a few were needed compared to wood trays. Once in Japan, the roe is repacked in the traditional wood trays and marketed through normal channels.

The proximity of the markets and the use of experienced labor ensured that the appearance of the repacked product was good. The only drawback was the extra time and cost needed to transport and repack the roe. Presently, fresh red sea urchin roe is being shipped to Japan primarily in wood trays, but some foam bulk trays are also used. The product form is largely determined by the current prices of both, and, recently, roe packed in wood trays has generally yielded higher profits.

For the domestic market, wood trays and plastic "oyster" trays (Fig. 19), which are partitioned, have 5 or 10 depressions, and hold 100 or 200 g of roe, are used for sale through retail markets. Nearly all sushi restaurants prefer the wood trays, however.

Several attempts have been made to process sea urchins aboard vessels at sea. The principal advantages are proximity to the sea urchin supply, access to clean salt water, and easy disposal of waste products. Apparently the cost of maintaining crews and workers aboard the vessels for extended periods proved uneconomical.

In the early days of the fishery, processing plants were concentrated in Santa Barbara, but by 1984 plants were located in Los Angeles (four), Long Beach (two), Ventura (one), and Oxnard (one). Several plants stopped processing recently in San Diego, Los Angeles, Oxnard, and Santa Barbara. These are likely to resume processing when conditions are favorable. Periodically, red sea urchins are harvested in northern California near Fort Bragg and trucked to central and southern California for processing.

Several attempts have been made to process sea urchins in northern California, but none has proved successful for a sustained period. The chief problem appears to be inclement weather during winter when the market is most favorable. In addition to high seas, visibility is extremely poor during and after winter storms, making diving for sea urchins rather difficult and hazardous. Nevertheless, some small-scale processing is being carried out with sea urchins from Half Moon Bay to Fort Bragg to supply local sushi shops.

Processors indicate that about 35-45 experienced workers are needed to clean and pack 10 t of whole red sea urchins in wood trays in an 8-hour work day. When larger foam trays are used, the same amount can be processed by 25 workers if the roe need not be aligned in the trays. If careful packing is required, however, only a slight savings in labor is realized.

The plants process sea urchins around 200 days annually. In a typical operation, 4 persons crack the shells open, 12 remove the roe and do preliminary cleaning, 6 do the final cleaning, and 16 pack the roe in wood trays[6]. During periods of full production, some plants have 80 persons working 10-12 hours per day.

The quantity and quality of roe contained in sea urchins is vital to processors. Quantity is by and large a seasonal phenomenon, as the amount of roe depends in part on the reproductive state of the sea urchins. However, nutritional state is important, and areas devoid of preferred algae produce sea urchins with poor yield or poor color.

We were fortunate in being allowed to examine the production log of a southern California processor, and we have constructed a graph (Fig. 20) of the yield of premium roe processed in 1975-76. The figure includes only roe packed in trays for the fresh roe market.

[13]The only known domestic tray maker is Matsumoto, Inc., 411 E. 5th St., Los Angeles, Calif.

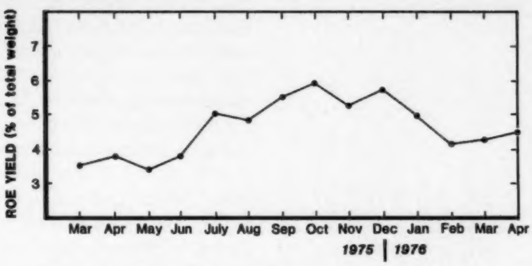

Figure 20.—Yield of sea urchin roe at a commercial processing plant. Only good quality roe sold fresh is included in the yield.

The production curve is similar to the reproductive cycle of red sea urchins (Fig. 4). The yield is lower because off-colored roe is discarded, some roe is inevitably lost during processing, and cooked and salted roe are not included in the data. Further, the gonad index given in Figure 4 is based on drained weight of sea urchins, while the production yield is based on total weight at dockside.

Roe color is exceedingly important in marketing. Clear, bright yellow or orange roe is best for the fresh market. As many as eight color grades are used by California processors, and all dark or discolored roe is discarded. For salted roe, the preferred color is orange, which is the color of high quality bottled salted roe made with Japanese sea urchins.

In the California fishery we noted that orange roe was exclusively from male red sea urchins while yellow roe was usually found in females. Bernard (1977) and Kramer and Nordin (1975) found the same relationship in red sea urchins from British Columbia, and the latter found no cyclic changes in color of the roe. Dark brown roe represents gonads degenerated because of starvation.

In addition to having good color and appearance, best quality roe is firm, small (less than 5 cm), and free of leaking fluids. Some processors feel that poor quality roe tends to occur in greater frequency in large (old) urchins, and for this reason they discourage harvest of the very large red sea urchins.

Persons in California wishing to buy and process sea urchins must obtain a wholesale fish dealers and preservers license ($65) from the Department of Fish and Game. In addition, the wholesaler is responsible for keeping records of all sea urchins purchased, and for paying a tax of $2.87/t of whole sea urchins bought.

Shipping and Marketing

Fresh roe is shipped to Japan by air freight, principally from Los Angeles International Airport. A freight forwarder consolidates products from several firms to take advantage of lower bulk-rate charges for air freight. Since carriers do not use refrigerated containers, each processor must include adequate artificial coolant in individual shipping cartons. Unit cost for air freight depends on the quantity shipped. Amounts under 100 kg are charged $5.08/kg; between 100 and 200 kg, $4.40/kg; 200-300 kg, $2.85/kg; and over 300 kg, $2.16/kg. To this are added handling charges of $17 to $45 per shipment, depending on the number of cases of roe shipped[14].

Steamed roe is often air-shipped to Japan, but it can also be frozen and sent by sea, as are all salted and frozen products. The basic shipping charge is presently $388/t. Other charges (insurance, labor, overland freight, etc.) are additional costs, as are surcharges for adjustments based on current fuel and currency rates[15].

[14]Mr. Kagawa, "K" Line Air Service, Inc., Redondo Beach, Calif. Personal commun.
[15]T. Saito, Pacific Marine Products Corporation, Ventura, Calif. Personal commun.

Sea urchin roe for the domestic market is shipped in insulated cartons containing coolants similar to those used in overseas shipment. Both truck and air transport are used, depending on distance.

The short shelf life of fresh sea urchin roe makes it imperative that the product be handled expeditiously. Fresh roe is usually shipped by air freight to Japan within 30 hours after delivery of the sea urchins at dockside by divers. Shipment timing is important because all imported food undergoes agricultural inspection and customs clearance at the receiving airport in Japan. Spot checks are also made by health officials to monitor levels of bacterial contamination. It is best to ship sea urchins from Los Angeles on flights that depart around midnight, as they arrive before dawn in Tokyo after 11-12 hours. Shipments that arrive late in the day are held over for inspection the following day. Shipments are not made on Fridays, because arrival date is Sunday in Japan, or on Sundays, when most U.S. processors suspend operations.

After official clearance, the roe is held overnight in refrigerators until early the next morning when auctions are held at the Metropolitan Central Wholesale Fish Market, located in Tsukiji, Tokyo. Bulk-packed roe is trucked directly from the airport to outlying regions, particularly to Miyagi Prefecture, about 325 km from Tokyo. There the roe is repacked in standard wood trays before being marketed.

Most of the sea urchin roe produced in California is marketed fresh in Japan, but an increasing amount of fresh roe is being packed in wood trays for the growing domestic sushi trade. Small amounts packed in plastic oyster trays are also sold in U.S. retail outlets. The total amount sold in the United States is unknown, but is thought to be on the order of 30-40,000 wood trays per month, which we estimate to be about 25 percent of the average amount sent to Japan.

In Japan, fresh U.S. roe packed in wood trays is sold primarily at the Tsukiji Market through auction. The roe is sold in lots (bundles) of 11-13 trays. In other cities, sea urchin roe is sold

through auction or directly to major wholesalers. Bulk-pack fresh roe, repacked in Japan in traditional wood trays, is sold in many cities through auction and direct sales. Salted, steamed, or baked roe is usually sold through brokers to manufacturers that specialize in preserved sea urchin roe products.

Several American processors sell sea urchin roe to Japanese trading firms at a fixed price so they are not subjected to the vagaries of auctioning. Some processors sell their own products at auction through brokers, however. These brokers receive about 5 percent of the sales price for their services. The auctioneers, called primary wholesalers, receive 5.5 percent of the auction price for handling the product. In addition, an import customs duty of 10 percent is assessed on fresh roe, and 7 percent on salted roe. These duties are paid on the basis of the bill of sale if the roe has been sold outright. If not, a small down payment is required, and the balance of the duty is paid after the primary wholesaler reports the selling price to the customs office.

As of 1984, divers were paid about $400-500/t for red sea urchins. The prices usually correspond to the high demand in winter, low yield during spring, and low demand in summer. To encourage harvesting of good quality sea urchins, some processors offer bonuses when high roe yields are achieved.

As mentioned, the prices paid at the auctions in Japan are based on supply and demand. Of course, quality is always of primary importance, and domestic roe always brings the highest prices. As the Japanese sea urchin fishery is mainly a spring-summer fishery, prices are generally lower during those months because of high domestic production (Mottet, 1976). Around the middle of August, seasonal monsoons depress fishing effort; at the same time, several species of sea urchins start reproductive activity, and fisheries for those species are curtailed. Then imports need to be increased to fill the demand.

The United States and the Republic of South Korea are presently the largest exporters of sea urchin roe to Japan. The

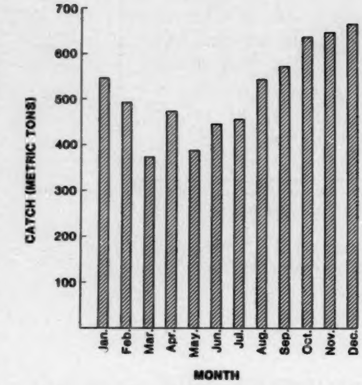

Figure 21.—Average California catch, by month, of red sea urchins, 1973-83. Source: California Department of Fish and Game.

demand and price are especially high during the holiday season near the end of the year. Thus the average catch by month in the California sea urchin fishery (Fig. 21) reflects the price structure. But the lower catches from March through July are also related to low gonad yields after the spawning season.

Processors in the United States sometimes sell their products to Japanese brokers at a flat annual price which reflects the value at both the high and low demand periods. Often by agreement the volume is kept minimal in the spring and summer to avoid big losses. However, the plants have to operate even during unprofitable periods, because of the need to keep key personnel employed.

Processors and buyers sometimes resort to freezing roe during the summer when Japanese prices are low. The frozen roe is held several months until prices are better, and though premium prices are never paid for frozen roe, the profits are a bit better than selling fresh roe in summer.

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The Columbia River Estuary: An Important Nursery for Dungeness Crabs, *Cancer magister*

ROBERT L. EMMETT and JOSEPH T. DURKIN

Introduction

Dungeness crab, *Cancer magister*, occur from Unalaska, Alaska, to Magdalena Bay, Mexico (Schmitt, 1921) and are one of the most important crustacean fisheries from California to Washington. Only pandalid shrimp landings are greater in terms of weight (PMFC, 1983).

Because of the commercial importance of the Dungeness crab, their reproductive biology and life history have been studied extensively. Butler (1960) found that female crabs reach sexual maturity at 2 years when they are about 100 mm in carapace width. Males mature at the same age, but with most active breeding activity beginning at 3 years or 140 mm. Copulation occurs in May-June (Cleaver, 1949), immediately after the female has molted and is soft-shelled; premating and mating behavior is lengthy (Snow and Nielsen, 1966).

Egg fertilization and extrusion occur in September-October in California (Orcutt, 1978), October-December in Washington (Cleaver, 1949), and September-February in British Columbia (Butler, 1956). Females carrying eggs can be found in Oregon waters from October to March (Waldron, 1958). Eggs adhere to the pleopodal hairs on the female crab's abdomen, forming a bright orange "sponge," where they remain until they hatch. Up to 2,500,000 eggs can be found in a clutch (Wickham, 1980), although the actual number which hatch is usually less (Wild, 1980). The eggs hatch in the spring, 60-130 days after extrusion, depending on temperature.

Newly hatched larvae are planktonic until becoming juveniles; larvae undergo five zoeal stages and one megalops stage, requiring 130-160 days, before metamorphosing to the first juvenile instar (Poole, 1967). Larvae can be found off the Oregon coast from January until late May (Lough, 1976) and appear to be held in the nearshore areas by strong alongshore and onshore components of the surface currents and by their own behavior (Lough, 1976). They are about 7 mm wide at the first juvenile instar (Waldron, 1958; Butler, 1961) and can be expected in Oregon coastal waters beginning in May (Waldron, 1958). Crabs grow logarithmically, and by 3.5 years of age many are large enough to enter the commercial and sport fisheries (Butler, 1961).

The California Department of Fish and Game (CDFG, 1981) has shown that the San Francisco Bay complex and nearshore areas are important juvenile Dungeness crab nurseries. The objective of our study was to ascertain if the Columbia River estuary and its adjacent coastal areas are important crab nursery habitat.

Methods

Data were collected during four bottom trawl surveys conducted by personnel from the National Marine Fisheries Service Field Station at Hammond, Oreg., between 1973 and 1982. The four surveys were as follows:

1) Columbia River Estuarine Trawl Survey, 1973-74—Seventeen areas in the Columbia River estuary were sampled monthly from July 1973 to June 1974 with a 5 m semiballoon shrimp trawl (Fig. 1). Overall mesh size (stretched) was 38.1 mm, with a knotless 12.7 mm liner inserted in the cod end. Figure 1 depicts the areas sampled for 2-10 minutes with 5-minute tows being most numerous. Occasionally more than one tow was done at each area; some areas were not sampled during all months.

2) Waterways Experiment Station (WES) Trawl Survey, 1974-76—Five nearshore coastal sites adjacent to the mouth of the Columbia River (Fig. 2) were sampled monthly from September 1974 to April 1976. Crabs were collected with an 8 m semiballoon shrimp trawl which had mesh identical to that of the trawl used in the Columbia River Estuarine Trawl Survey. Each sampling tow was 5 minutes in duration.

3) Columbia River Estuary Data Development Program (CREDDP) Trawl Survey, 1980-81—Twenty-two Columbia River estuary sites (Fig. 3) were sampled monthly from February 1980

ABSTRACT—Carapace width frequency distribution data for Dungeness crab, Cancer magister, *were collected during four bottom trawl surveys conducted between 1973 and 1982; two surveys were in the Columbia River estuary and two in coastal areas adjacent to the mouth of the Columbia River. The data indicate large differences in width frequency between coastal and estuarine crab populations: Coastal populations had few and estuarine populations had many 1+ (year) age crabs. Based on the indication that 1+ age crabs are found primarily in estuaries, it appears that estuaries play an important role in Dungeness crab life history.*

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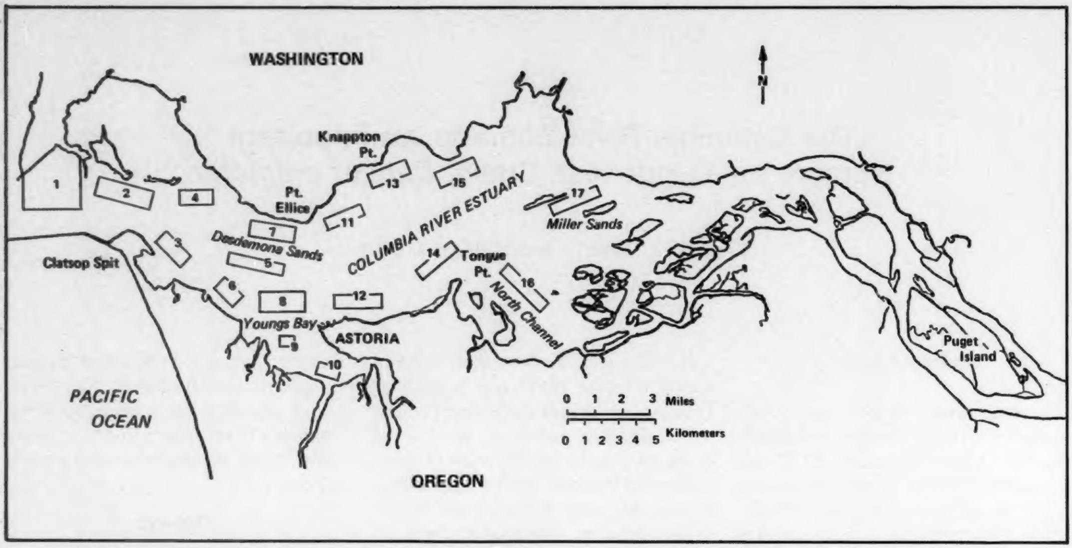

Figure 1.—Locations of the 17 areas in the Columbia River estuary sampled monthly from July 1973 to June 1974 with a 5 m trawl.

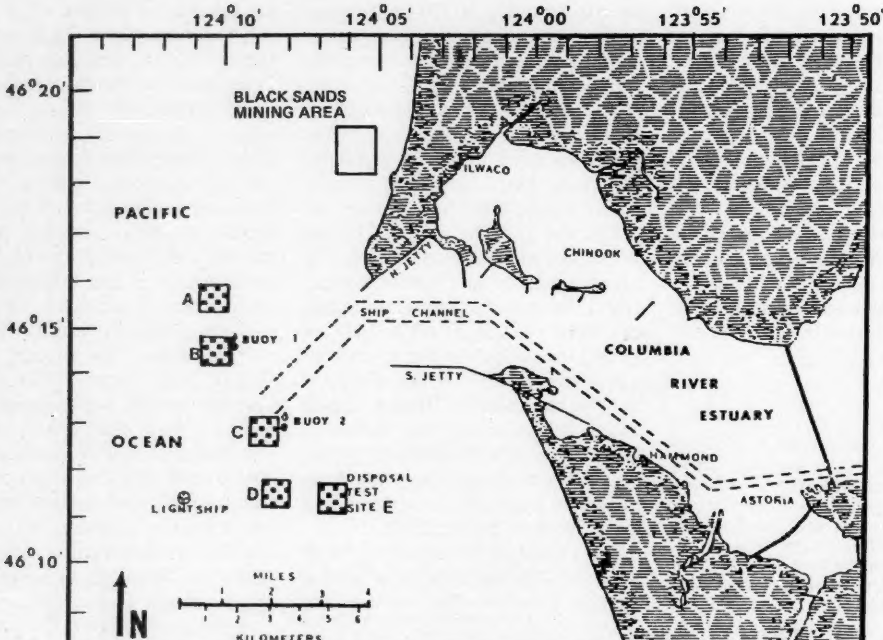

Figure 2.—Locations of five coastal 8 m trawl sites sampled monthly from September 1974 to April 1976 (A-E) and one coastal site (Black Sands Mining Area) sampled bimonthly May 1981 to May 1982.

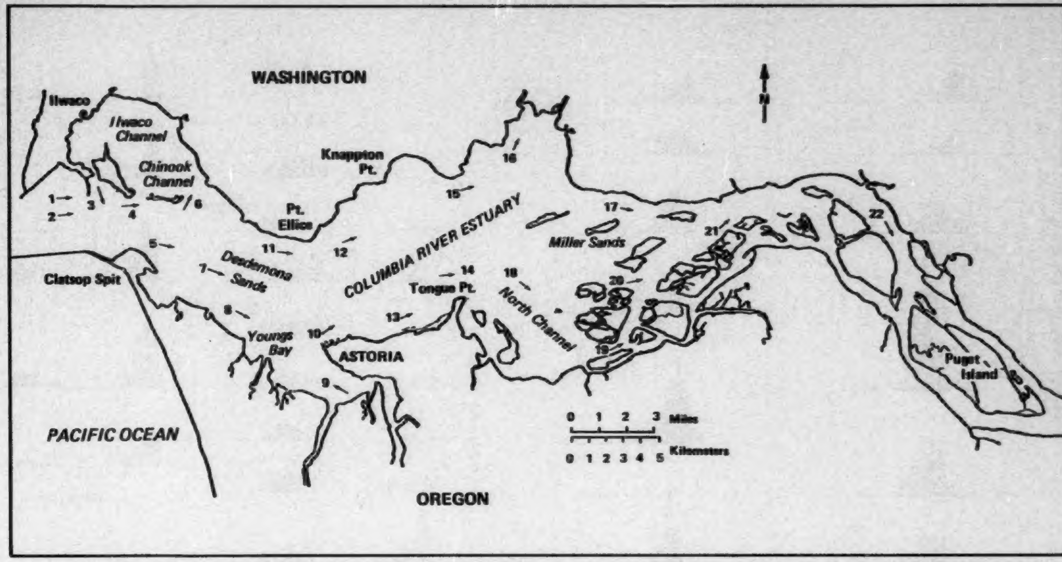

Figure 3.—Locations of 22 stations in the Columbia River estuary sampled monthly from February 1980 through July 1981 with an 8 m trawl.

through July 1981 (after October 1980, not all sites were sampled). An 8 m trawl, the same type as used in the WES Trawl Survey, was towed at each site for 5 minutes.

4) Black Sands Mining Trawl Survey, 1981-82—During this survey, one area in and adjacent to a proposed black sands (magnetite) mining area (Fig. 2) was sampled every 2 months from May 1981 through May 1982, except November 1981 when severe winter weather prevented sampling. The sampling gear and methods were identical to those used during the WES Trawl Survey and CREDDP Trawl Surveys except that a cod-end liner was not used in the trawl for all the sets.

All Dungeness crabs captured during the four surveys were measured anterior to the 10th anteriolateral spines and weighed. When more than 50 crabs were captured in a single tow, a representative subsample of 50 was measured and weighed; the remainder were counted and then weighed as a group.

In this article, carapace width frequency data are reported. Information regarding total catches and sex ratios for the WES Trawl Survey can be found in Durkin and Lipovsky (1977). Crab information from the other surveys can be obtained from the senior author.

Results and Discussion

Carapace width frequency distributions of captured Dungeness crabs are shown in Figures 4-7. There is wide variation in the width frequency distributions between coastal (Fig. 5, 7) and estuarine (Fig. 4, 6) crab populations. The estuarine population had an abundance of crabs between 50 and 100 mm in width, whereas the coastal crab population had larger and smaller specimens but very few in this size range. Defining age as beginning with metamorphosis from megalops larvae, and using age-width information of Butler (1961) and Armstrong et al.[1], the 50-100 mm sized crabs were primarily in the 1+ (year) age class.

Dungeness crab recruitment can be highly variable from year to year (Gotshall, 1978; California Department of Fish and Game, 1981); it is possible that the data from 2 years of coastal sampling represent extremely poor years for recruitment of the 1+ age class. We feel this is unlikely since 1977-78 commercial landings, when the 1975 1+ age class would have entered the fishery, were better than average (PMFC, 1983). Two separate ocean surveys providing the same carapace width frequency distributions imply that the absence of 1+ age crab in coastal waters adjacent to the Columbia River is a natural event.

The California Department of Fish and Game (CDFG, 1981) observed that many 0+ age crabs (young-of-the-year) move into the San Francisco Bay complex as a result of prevailing currents and subsequently (after about a year) move back to coastal waters. In the Columbia River, all age groups use the estuary, with the 1+ age class being extremely abundant. At about 2 years of age (100 mm), many crabs apparently migrate to coastal areas, although a few

[1]Armstrong, D. A., B. G. Stevens, and J. C. Hoeman. 1981. Distribution and abundance of Dungeness crab and the Crangon shrimp and dredging-related mortality of invertebrates and fish in Grays Harbor, Washington. Unpubl. manuscr., 348 p. School of Fisheries, University of Washington, Seattle, WA 98195. (Prepared for the Washington Department of Fisheries and the U.S. Army Corps of Engineers, Seattle District, under contract DACW67-80-C-0086.)

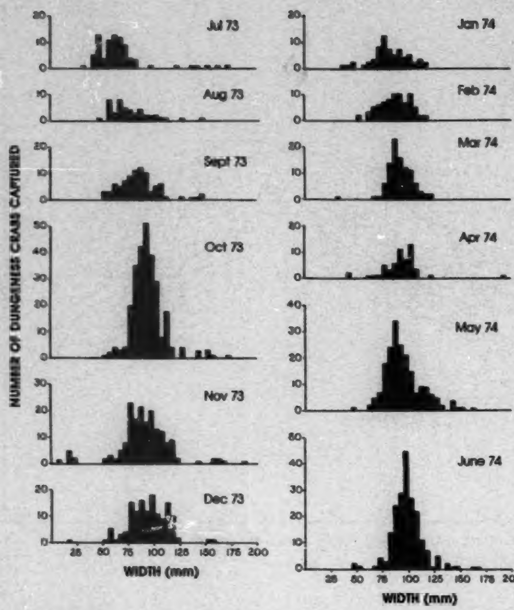

Figure 4.—Width frequency distributions of Dungeness crabs, *Cancer magister*, captured by a 5 m trawl at 17 areas in the Columbia River estuary from July 1973 through June 1974.

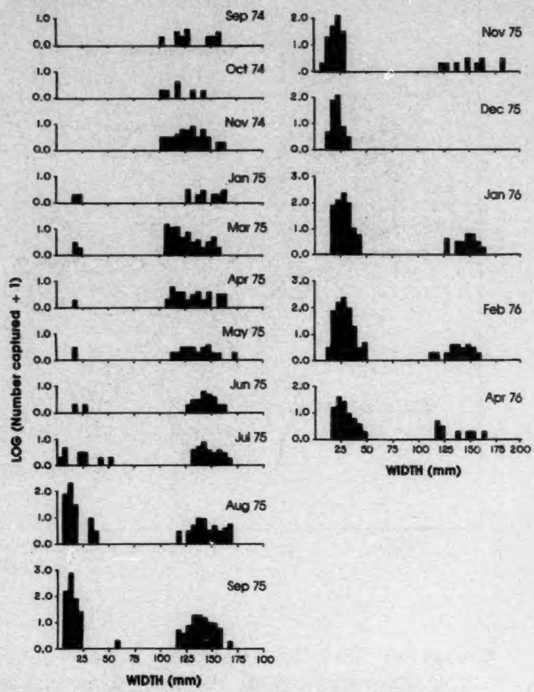

Figure 5.—Width frequency distributions of Dungeness crabs, *Cancer magister*, captured by an 8 m trawl at five coastal sites adjacent to the Columbia River estuary, September 1974 through April 1976.

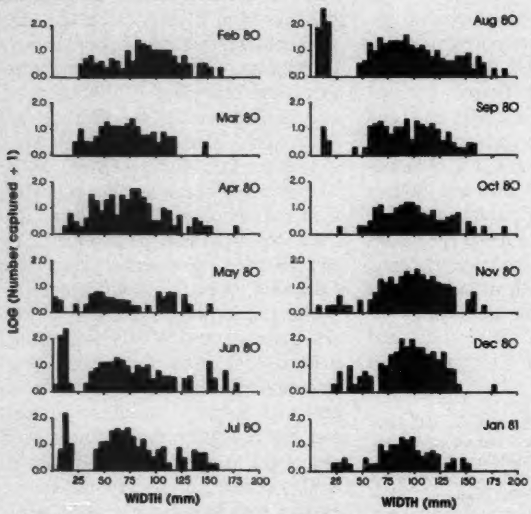

Figure 6.—Width frequency distributions of Dungeness crabs, *Cancer magister*, captured by an 8 m trawl at 22 stations in the Columbia River estuary from February 1980 through January 1981.

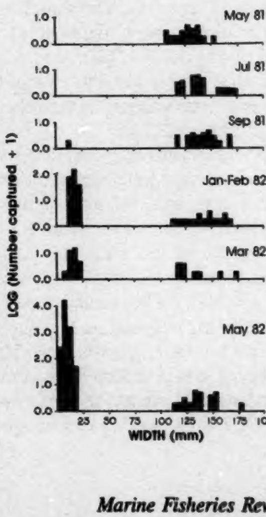

Figure 7.—Width frequency distributions of Dungeness crabs, *Cancer magister*, captured by an 8 m trawl at one coastal site (a proposed magnetite mining area) from May 1981 through May 1982.

remain.

Our data are limited because the coastal surveys were not conducted simultaneously with the estuarine sampling. Also, the coastal surveys only sampled depths from 12.2 to 36.6 m in the vicinity of the mouth of the Columbia River estuary.

Data in this article indicate that the Columbia River estuary is an important nursery area for juvenile crabs, particularly the 1+ age class. Grays Harbor, Wash., (69 km north) has also been shown to be an important nursery area for Dungeness crabs[1], but little information is available concerning other Pacific Northwest estuaries. Crab surveys are needed in other estuaries and in adjacent coastal waters to identify to what extent estuaries are used by juvenile crabs, and if estuarine habitat may be a limiting factor in Dungeness crab abundance.

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Shelf Life Extension of Drawn Whole Atlantic Cod, *Gadus morhua*, and Cod Fillets by Treatment With Potassium Sorbate

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Introduction

Despite attempts to improve handling practices and sanitation, seafoods remain one of our most perishable foodstuffs. The primary limiting factors in the shelf-life of seafoods is the unavoidable contamination by spoilage bacteria during processing, and by their proliferation during storage. The method studied in this work seeks to preserve fish and extend its shelf life by the use of a safe chemical preservative, in this case potassium sorbate (KS) which has been shown to inhibit those bacteria responsible for spoilage odors.

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Sorbic acid and its water soluble salt, potassium sorbate, are classified by the U.S. Food and Drug Administration as GRAS (generally recognized as safe) when used at the lowest level to accomplish its function. Sofos and Busta (1981) have reviewed the use of sorbates as a food perservative in great detail. Debevere and Voets (1972) showed that treatment of Atlantic cod, *Gadus morhua*, fillets with 0.135 or 0.4 percent KS inhibited aerobic bacterial growth, with sorbate being particulary effective in repressing those organisms responsible for formation of trimethylamine (TMA), the compound that produces the typical spoiled fish odor. Chung and Lee (1981, 1982) demonstrated that 1.0 percent KS in English sole, *Parophrys vetulus*, homogenate delayed the onset of logarithmic bacterial growth (or lag phase) to 6 days at 0°C, but did not alter the spoilage flora when the fish was stored aerobically. And, Tomlinson et al. (1978) reported that the addition of 0.2 percent KS to half-strength refrigerated seawater used for holding whole Atlantic cod could extend the sensory shelf life of fillets from the fish by 30 percent.

Besides inhibiting spoilage bacteria, KS has been shown to inhibit foodborne pathogens in seafoods. Robach and Hickey (1978) reported inhibition of three strains of *Vibrio parahaemolyticus* in flounder, *Hippoglossus hippoglossoides*, and blue crab, *Callinectes sapidus*, homogenate by 0.05 percent sorbic acid. Lynch and Potter (1982) demonstrated substantial inhibition of *Staphylococcus aureus* in minced Atlantic cod stored at 7° and 15°C.

Our study was done to determine the effect of a KS dip on the shelf life of commercially filleted Atlantic cod cut from fish 1-5 days post-capture. A secondary goal was to determine the shelf life of fillets cut from drawn Atlantic cod held in chilled seawater containing KS. This procedure simulated processing plant holding of fish over a weekend or for later processing, and could also be applicable to certain fishing vessel holding systems.

ABSTRACT—Potassium sorbate has been used as an antifungal and antimicrobial agent in foods for many years, and has been generally recognized as safe (GRAS) by the U.S. Food and Drug Administration. Since its specific action on bacterial growth or inhibition has not yet been clearly estalished, especially in seafoods, an empirical experiment was conducted wherein fillets cut from Atlantic cod, Gadus morhua, *of known post-capture age (i.e. 1, 3, and 5 days) were dipped in 2.5 and 5.0 percent fresh potassium sorbate, individually packaged in either polyethylene or polyethylenephthalate pouches, iced, and given sensory examinations at 2- to 3-day intervals until the end of acceptable shelf life (when any sensory attribute average at either the raw or cooked evaluation fell below 5.0 (borderline) on a 9-point objective scale). We found that dipping fillets in 2.5 and 5.0 percent potassium sorbate and individually packaging them in plastic film, especially oxygen resistant polyethylenephthalate, was definitely beneficial in extending the iced shelf life of the fillets, in some cases more than doubling it. Dipping in potassium sorbate was effective in retarding trimethylamine formation. Shelf life was not appreciably extended for fillets cut 1, 3, and 5 days post-capture from whole, gutted cod that had been stored in chilled sea water containing 0.5 percent potassium sorbate for 2 days prior to filleting and sensory examination.*

Materials and Methods

Dipping Fish Fillets in Potassium Sorbate

Commercially filleted and skinned Atlantic cod fillets cut from 1-, 3-, and 5-day-old iced fish were used. Each fillet was dipped about 15 seconds in cold, fresh 2.5 or 5.0 percent (w/w) KS solutions (<24 hours old), placed either in 0.75 mil low-density polyethylene or

4.5 mil Scotchpak[1] (polyethylenephthalate) pouches which were securely tied off with wire twine. Control fillets were identically packaged but not dipped. All pouches were then placed in ice and held at 0.5°C. These films were used to determine the influence on shelf life of packaging the fish either in a highly oxygen permeable package (polyethylene) or one very low in oxygen permeability (polyethylenephthalate). One mil polyethylene has an oxygen transmission rate of 500-1,000 cc/100 inches^2 in 24 hours at atmospheric pressure, while 4.5 mil Scotchpak has an oxygen transmission rate of about 5/cc/100 inches^2 in 24 hours (Fitz[2]).

Sensory Evaluation

Raw Fillets

At 2- to 3-day intervals, fillets from each treatment lot (control, 2.5 percent dip, and 5.0 percent dip) were removed from iced storage and presented for evaluation to a 12-member laboratory panel experienced in the evaluation of fishery products. Each sample was evaluated for appearance, odor, and texture on a 9-point objective scale where 9 = excellent, 8 = very good, 7 = good, 6 = fair, 5 = borderline, 4 = slightly poor, 3 = poor, 2 = very poor, and 1 = inedible.

Cooked Fillets

The fillets were then cut into twelve 1.5×1.5-inch squares, placed in foil-covered pans in a double boiler, steamed for 12 minutes, and then served to the panel on coded plates. The samples were evaluated for appearance, odor, flavor, and texture using the same 9-point scale.

The acceptable shelf life of each sample was considered at an end when the average of any sensory attribute such as odor or flavor, either in the raw or cooked tests, fell below 5.0 (borderline). If, for example, an average for a sensory attribute scored below 5.0 on day 16 of storage, and it was acceptable on day 13, its shelf life would be 14-15 days and would be reported as 14.5 for statistical purposes. Each experiment on fillets cut from 1-, 3-, and 5-day-old cod, was repeated three times and the results were averaged.

TMA Analysis

Fillet samples dipped in 2.5 and 5.0 percent KS as well as nondipped controls were sent to the Monsanto Company Food Analysis Laboratory, St. Louis, Mo., for TMA and microbiological analysis. These samples were stored at 2°C. At 3- to 4-day intervals, duplicate samples from each treatment were frozen. At the conclusion of the refrigerated storage period, all frozen samples were analyzed in triplicate for trimethylamine content by gas chromatography. The chromatograph was equipped with a nitrogen-phosphorus selective detector and temperature programmer. The column was 1×2 mm i.d. glass packed with 80/100 Chromosorb 103. (Conditions: Helium, 30 ml/minute; air, 60 ml/minute; hydrogen, 3.5 ml/minute; injection port, 200°C at 16°C/minute; detector, 300°C).

A 10 g sample of fish flesh was homogenized in 20 ml of 6 percent $HClO_4$. The mixture was filtered and 2 ml of filtrate was mixed with 2 ml n-amyl alcohol and 2 ml of 65 percent KOH. This mixture was heated at 60°C for 10 minutes, shaken 5 minutes, then centrifuged at 1,500 rpm for 5 minutes. One microliter of the supernatant was injected into the gas chromatograph, and the area of the peak at the rentention time of TMA was measured. Total aerobic bacterial plate counts were done on each sample taken for trimethylamine analysis.

Holding Drawn Fish in Chilled Seawater With KS

In this section, whole, drawn 4- to 6-pound cod 1, 3, and 5 days postcapture were held for an additional 2 days in 1) chilled sea water (CSW) only, 2) CSW containing 0.5 percent (w/w) of potassium sorbate, 3) fish from the same lot iced down in 100-pound boxes in the normal commercial manner (control). This procedure simulated plant holding conditions where a load of surplus fish caught or delivered on a Friday could be held over for the Monday market, without holding them iced in boxes or in holding pens aboard ship. After 2 days of CSW/KS storage, the fish were transferred to clean wooden boxes with perforated bottoms, reiced, and held at 33-34°F for sensory testing.

Raw Evaluation of Whole Fish

Every 2-3 days, two iced, CSW, and CSW/KS fish were withdrawn from iced storage. Ice and slime were washed off, and they were presented on coded trays for sensory evaluation.

For this assessment, panelists rated the drawn fish for the appearance of the skin, color and condition of the eyes, color of gills and gill mucus, flesh texture, and the odor and color of the gill and visceral cavities. Numerical evaluation was on the same 9-point system.

Raw and Cooked Evaluation of Fillets

Each fish was then filleted and skinned and the raw fillets were presented to the panelists for evaluation of appearance, odor, and texture. The fillets were then steamed as described and presented to the panel for evaluation. Shelf-life end points were determined as in the previous experiment. Each of these studies on whole drawn cod were done twice and the shelf-life end points were averaged.

Results and Discussion

KS Dipped Fillets

Sensory Analysis

Tables 1, 2, and 3 show the shelf life of cod fillets cut from 1-, 3-, and 5-day-old fish, dipped in 2.5 and 5.0 percent KS, and packaged in either 0.75 mil low-density polyethylene or 4.5 mil Scotchpak pouches. Shelf-life end points and their averages are given for each treatment.

The results indicate that dipping these fillets in KS solutions extended their refrigerated shelf life appreciably, in some cases more than doubling it. The fact that shelf life in some cases was much longer than that of fillets of the

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.
[2]J. R. Fitz, Kapak Corp., 5305 Parkdale Dr., Minneapolis, MN 55416. Personal commun., 1985.

same age in another experiment cannot be explained, but it may have been due to inadvertent receipt of fillets cut from fish of lower quality—possibly from fish from the bottom of the fish hold or from poorly iced fish. In several cases, low scores from one or two panelists terminated shelf life prematurely.

Shelf life extension of the dipped fillets, especially those individually packaged in Scotchpak, tended to be longer with increasing age of the fish from which they were cut. This may be due to the microbiological protection of the flesh from contamination by the unbroken skin during the 3-5 days of iced storage.

The most effective KS treatment for extending fillet shelf life was a dip in 5 percent KS with individual packaging in 4.5 mil Scotchpak and storage at 33-34°F. At no time did any panelist detect any odor or taste that could be attributable to potassium sorbate.

TMA Analysis

Table 4 shows the results of the TMA analyses for the control and KS-dipped fillets. Potassium sorbate was very effective in retarding TMA formation. This observation is consistent with the results of Debevere and Voets (1972) and their conclusion that sorbate is particularly inhibitory toward seafood "spoilers." Bacterial reduction was not evident in KS-dipped fillets. Counts for the controls and dipped fillets were about the same, although work by Kruk and Lee (1982) with *Escherichia coli*, showed that sorbate was inhibitory toward TMAO reductase activity. The reduction in TMA production is quite apparent in the sensory scores our panelists assigned to fillets treated with sorbate, since TMA is a principle early sensory indicator due to its characteristic spoiled fish odor. Nondipped control fillets were rejected due to strong TMA production. Dipped fillets were finally rejected due to other odors (musty).

Table 1.—Shelf life of cod fillets cut from 1-day-old fish and dipped in potassium sorbate.

Treatment	Packaging	Shelf life (days)[1] Exp. I	Exp. II	Exp. III	Average
Control (no dip)	Polyethylene	9.5	6.0	10.5	8.7
	Scotchpak	9.5	8.5	10.5	9.5
2.5% KS dip	Polyethylene	10.5	9.5	15.0	11.7
	Scotchpak	10.5	15.0	17.5	14.3
5% KS dip	Polyethylene	10.5	15.0	17.5	14.3
	Scotchpak	13.5	19.5	19.0	17.3

[1]To determine shelf life from the day of dipping in KS, deduct 1 day from these figures.

Table 2.—Shelf life of cod fillets cut from 3-day-old fish and dipped in potassium sorbate.

Treatment	Packaging	Shelf life (days)[1] Exp. I	Exp. II	Exp. III	Average
Control (no dip)	Polyethylene	7.5	11.5	12.5	10.5
	Scotchpak	7.5	11.5	14.5	11.2
2.5% KS dip	Polyethylene	15.0	18.5	16.5	16.7
	Scotchpak	15.0	18.5	19.5	17.7
5% KS dip	Polyethylene	15.0	18.5	19.5	17.7
	Scotchpak	15.0	18.5	22.0	18.5

[1]To determine shelf life from the day of dipping in KS, deduct 3 days from these figures.

Table 3.—Shelf life of cod fillets cut from 5-day-old fish and dipped in potassium sorbate.

Treatment	Packaging	Shelf life (days)[1] Exp. I	Exp. II	Exp. III	Average
Control (no dip)	Polyethylene	11.5	13.0	10.5	11.7
	Scotchpak	9.5	13.0	13.0	11.8
2.5% KS dip	Polyethylene	16.5	17.5	17.5	17.2
	Scotchpak	18.5	21.5	17.5	19.2
5% KS dip	Polyethylene	21.5	17.5	17.5	17.2
	Scotchpak	21.5	21.5	17.5	20.2

[1]To determine shelf life from the day of dipping in KS, deduct 5 days from these figures.

Table 4.—Trimethylamine content (ppm) of Atlantic cod fillets dipped in KS and nondipped, (control), and stored in either polyethylene (P) or Scotchpak (S).

Days Storage at 2°C	Nondipped P	Nondipped S	2.5% KS dip P	2.5% KS dip S	5.0% KS dip P	5.0% KS dip S
0	115	144	90	94	110	97
3	73	102	58	58	49	74
7	385	345	65	120	54	117
12	1,450	1,310	78	92	53	71

Table 5.—Shelf life of drawn cod held in CSW with 0.5 percent KS for 2 days and then in ice.

Days boxed and in iced storage	Days held in CSW (control)	Days held in CSW and 0.5% KS	Shelf life of fillets cut from fish held in CSW and 0.5% KS	Total acceptable shelf life for fillets cut from control and treated fish
12	0			11.5
1	2			11.5
1		2.0	10.3	13.3
14	0			13.8
3	2.0			14.3
3		2.0	11.0	16.0
11	0			10.0
5	2.0			8.8
5		2.0	3.0	10.0

Drawn Fish Held in CSW With KS

Table 5 shows the shelf life of whole drawn cod, 1, 3, and 5 days post-capture, held in 0.5 percent KS in CSW for an additional 2 days, then reiced in boxes and stored at 1°C. These fish, both raw and cooked, were compared with conventionally iced fish and with fish held in CSW (controls).

Storage of 1- and 3-day-old fish in 0.5 percent KS in CSW did extend their shelf life over the iced and CSW treated controls, but only slightly. This difference in shelf life does not appear to warrant storage of fish in CSW containing 0.5 percent KS. Possibly storage in

CSW containing more than the percentage of KS used for this work would prove beneficial.

Conclusions

The use of a potassium sorbate dip for Atlantic cod fillets cut from iced fish up to 5 days old was definitely beneficial in extending the shelf life of the packaged fillets, especially those packaged in a relatively oxygen impermeable film like Scotchpak. In some cases, the shelf life of the dipped, iced fillets was more than double that of nondipped controls. Dipping fish fillets in both 2.5 and 5.0 percent potassium sorbate inhibited TMA formation, one of the principle and early indicators of fish spoilage. At no time did the panelists smell or taste the presence of potassium sorbate. This method, therefore, is recommended for commercial use. Holding 1- to 5-day-old fish in CSW containing 0.5 percent KS for 2 days was slightly useful in extending shelf life, but is not considered economically feasible.

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Fatty Acid Composition of Commercial Menhaden, *Brevoortia* spp., Oils, 1982 and 1983

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Introduction

Menhaden, *Brevoortia* spp., oil, the commercial fish oil produced in greatest volume in the United States, has been analyzed for its fatty acid composition by several investigators in recent years (Ackman et al., 1976, 1981; Ackman, 1980; Dubrow et al., 1976). In a summary of published information on fatty acid composition of menhaden oils, Ackman et al. (1981) showed that oils of this fish from colder waters of the Atlantic Ocean are somewhat more unsaturated than those of fish from warmer waters of the Gulf of Mexico. However, most of these data were obtained by chromatographic methods that have become outmoded for the analysis of marine fatty acids.

Ackman (1980) listed the fatty acids of Atlantic and Gulf coast menhaden oils, determined by modern high-resolution wall-coated open-tubular gas-liquid chromatography (GLC). There was, however, no indication of whether these oils were seasonal or annual composites. More recently, Stansby (1981) tabulated the percent ranges of 14 fatty acids of menhaden oils derived from both published and unpublished studies. Included in his report were narrower ranges of values in oils that had been composited annually to eliminate season as a variable. From this, he concluded that seasonal variation is greater than geographic variation in menhaden oils.

As none of these studies has clearly defined the extent of annual, seasonal, and geographic variations in fatty acid composition of commercial menhaden oils, this study was designed with that goal in mind. Compositional differences, if of sufficient magnitude, might suggest the feasibility of selective harvesting of menhaden, depending upon desired oil properties and intended markets for the oil.

Almost all fatty acids of marine plants and animals contain an even number of carbon atoms, generally from 12 to 24, in the molecule. If no double (olefinic) bonds are present, these fatty acids are known as saturates. Unsaturated fatty acids contain from one (monoenes) to a maximum of six (polyunsaturates) double bonds. The fatty acid shorthand notation used in this report has been suggested by the IUPAC-IUB Commission on Biochemical Nomenclature (1977) as a replacement for the "ω" (omega) notation, widely used for many years, but there is no basic difference in the two systems. Both specify, first, the number of carbon atoms and, second, the number of double bonds in the fatty acid molecule. This is followed by the position of the terminal olefinic bond relative to the hydrocarbon end of the molecule, i.e., the end-carbon chain, designated as "ω x" or "(n-x)". The symbols "ω" and "n-" are synonomous and "x" equals the end-carbon chain length. Thus 20:5ω3 and 20:5(n-3) both specify a fatty acid molecule that contains 20 carbons and five double bonds and is a member of the omega-3 family of fatty acids.

Materials and Methods

Sample Preparation and Storage

During the 1982 fishing season, 12 commercial reduction plants partici-

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ABSTRACT—Throughout the fishing seasons of 1982 and 1983, samples of commercially-rendered menhaden, Brevoortia *spp., oils from the coasts of the Atlantic Ocean and Gulf of Mexico were composited monthly and shipped to the Charleston Laboratory of the National Marine Fisheries Service for analysis. The fatty acid compositions of these oil samples, 65 in 1982 and 63 in 1983, were determined by GLC on flexible fused silica, high-resolution capillary columns. A microcomputer was used to assist in identification of 36 selected fatty acids and to provide descriptive statistics. Of these 36 fatty acids, the mean values of 10 fatty acids of nutritional or biochemical importance were statistically tested for annual, seasonal, and geographic differences by ANOVA on a mainframe computer. While there were few if any differences in annual or seasonal means of fatty acids of Atlantic oils, 9 of the 10 fatty acids in the Gulf oils had significantly different* ($p < 0.001$) *seasonal means and 4 had annual means that differed significantly. The geographic means of both 18:1ω9 and 22:6ω3 were highly different, statistically, in the Gulf oils.*

pated in the sampling program, three on the Atlantic coast and nine on the Gulf coast. Atlantic coast plants included those of two companies in Reedville, Va., and one in Southport, N.C. Gulf coast plants were located in Moss Point, Miss. (3), Empire, La. (1), Houma, La. (1), Intracoastal City, La. (1), and Cameron, La. (3). During the 1983 fishing season, there were 11 participating plants; only the two Reedville plants provided samples from the Atlantic coast. A total of 65 oil samples was received in 1982 and 63 in 1983.

Within each plant, an equal portion of each day's production was set aside to create monthly composite samples, beginning in mid- to late-April on the Gulf coast and in June on the Atlantic Coast and continuing through the month of October at all plants. At the end of each month, after thorough mixing of the composites, subsamples were transferred to 250 ml amber glass bottles with Teflon-lined[1] caps and shipped to the Charleston Laboratory of the NMFS Southeast Fisheries Center. After mixing again on a rotary-action mixer, a portion of each sample was used to completely fill a 15 ml glass culture tube with Teflon-lined cap for storage at −10°C until all monthly samples had been received.

Chemistry and Chromatography

After warming to ambient temperature, each sample was transferred by a hexane rinse (about 20 ml) to a glass-stoppered 125 ml Erlenmeyer flask containing anhydrous crystalline Na_2SO_4. The air in the flask was displaced with N_2 and the contents shaken periodically for 1 hour to remove any contaminating water. The solution was then filtered through phase-separating filter paper into a 50 ml volumetric flask and made to volume with hexane. The concentration of oil in the solution was determined gravimetrically by transferring two 1.0 ml aliquots to tared aluminum weighing pans, evaporating the solvent in a 100°C oven for 30 minutes and reweighing the pans.

To prepare fatty acid methyl esters (FAME) for GLC, duplicate aliquots of the lipid solution, each containing about 35 mg oil, were transferred to two 15 ml conical centrifuge tubes and the solvent evaporated in a N_2 stream. Esters of the neat oil were prepared by the method of Christopherson and Glass (1969).

The esters were separated by GLC (Hewlett-Packard 5830A gas chromatograph) using a wall-coated open-tubular (capillary) flexible fused silica column, 50 m by 0.21 mm, coated with Silar 5-CP (Chrompack Inc., Bridgewater, N.J.). Helium was used as the carrier gas at 60 psig (4.5 kg/cm^2) and a column flow of 1 ml/minute. Nitrogen, the make-up gas, was provided at 40 psig and a flow of 30 ml/minute through the flame ionization detector. During analysis of the 1982 oils, initial analyses were carried out isothermally at 215°C, but as the column aged, resolution of early-eluting components decreased at this column temperature. This difficulty was overcome by carrying out later analyses using a two-step temperature program. The initial temperature of 200°C was held for 39 minutes, then increased to 215°C at 15°/minute to complete the analysis. For 1983 oils, a new column was installed just before beginning the analyses and all samples were analyzed isothermally at 205°C. The fatty acid composition of each sample was reported as area percent composition using a Hewlett-Packard 18850A GC terminal microprocessor.

Data Analysis

For analysis of 1982 data, retention times and percentages of the separated components of each sample were entered manually into a Radio-Shack Model III 48K microcomputer (Tandy Corp., Fort Worth, Tex.) and stored on floppy disks. The FAME were provisionally identified by means of a BASIC computer program that calculates equivalent chain length (ECL) values of the component FAME from their retention times (Jamieson, 1970), compares the ECL's with those of authentic primary and secondary standards, and reports probable identities. As Marmer et al. (1983) have noted, in studies involving GLC analysis of a large number of samples, complete computer automation is undesirable; human intervention is necessary to correct inevitable errors in peak identification or quantitation. Therefore, these tentative identifications were inspected and corrected as necessary with the Model III commercial word processor program, Superscripsit (Tandy Corp.), before any further data manipulation was attempted. Other BASIC programs calculated and tabulated mean percentages, standard deviations, and ranges of values of 36 fatty acids of particular interest in oils from the two regions. From these data, 10 fatty acids were selected for their nutritional or biochemical importance for more sophisticated statistical analysis.

Before the 1983 oils were analyzed, the chromatographic system was interfaced with dedicated microcomputers. An interface board (Hewlett-Packard 18833A digital communications interface) was installed in the gas chromatograph which, under software control, now sends all data (retention times, area counts, and percentages) through an RS-232C serial interface to an Apple IIe 64K microcomputer (Apple Inc., Sunnyvale, Calif.) where they are recorded on floppy disk. When convenient, the data are then transferred to the Radio-Shack microcomputer, using the commercial communications program, Videotex Plus (Tandy Corp.). These disk files provide the data for the identification and descriptive statistics programs.

The mean percentages of the 10 fatty acids of nutritional or biochemical importance were statistically tested for annual, seasonal, and geographic differences by analysis of variance (ANOVA) on a Burroughs B7800 mainframe computer using the program BMDP2V of the BMDP computerized statistical package. The 1982 and 1983 data were analyzed separately using a two-way ANOVA to identify significant differences in seasonal and geographic mean percentages. For the combined 1982-83

[1]Mention of trade names, commercial firms, or specific products or instrumentation is for identification purposes only and does not constitute endorsement by the National Marine Fisheries Service, NOAA.

data, three-way ANOVA was used to calculate significant differences in annual, seasonal, and geographic mean values.

Results

Before beginning analysis of the 1982 oils, a preliminary experiment was carried out to determine the precision of the planned analytic methodology. One of the oils was selected, dried, and transferred with hexane to a 50 ml volumetric flask as described in the previous section. Eight aliquots of the lipid solution, each containing about 35 mg oil, were transmethylated and analyzed by GLC. Mean percentage, the standard deviation, and the number of necessary analytic replications as a function of the relative standard error of the mean were calculated for each of the 10 fatty acids selected as being of particular interest.

These calculations showed that a relative standard error of ⩽4 percent could be expected for each of the 10 fatty acids from a single analysis of each oil (Table 1). With duplicate analyses, a relative standard error of ⩽2 percent could be achieved for all fatty acids except myristic acid (14:0) which would require three analyses to give this relative standard error. Since each GLC analysis required about 72 minutes, not including the time needed to prepare the sample for analysis, three analyses were judged impractical in terms of the total time required for analysis and later data manipulation. Therefore, a duplicated analysis of each oil was accepted as a satisfactory compromise and suitable procedure.

From about 60 component fatty acids in the menhaden oils, 36 were selected for calculation of annual and geographic means over the two 6-month fishing seasons. These 36 fatty acids comprised ⩾96 percent of the total fatty acids in the oils. Branched-chain fatty acids (iso-, anteiso-, and isoprenoid acids) were omitted, as were a few minor components of uncertain identity. Twenty-five fatty acids with an annual mean percentage of ⩾0.2 percent for the years 1982 and 1983 are listed in Table 2 for Atlantic oils and Table 3 for Gulf oils. The annual mean percentages of the major fatty acids were similar in Atlantic and Gulf coast oils and, within experimental error, all fell within the broader ranges reported by Stansby (1981), with the possible exception of 16:0 (palmitic acid) in 1982 Atlantic coast oils. These values also agree well with those reported by Ackman (1980) for Atlantic and Gulf coast oils.

A three-way ANOVA of percentages

Table 1.—Precision of analytic methodology. Replication required to give 1-5 percent relative standard error of the mean (RSEM).

	RSEM				
Fatty acid	1	2	3	4	5
	Replication				
14:0	11	3	2	1	1
16:0	2	1	1	1	1
16:1(n-7)	3	1	1	1	1
18:0	3	1	1	1	1
18:1(n-9)	3	1	1	1	1
18:1(n-7)	3	1	1	1	1
18:4(n-3)	2	1	1	1	1
20:5(n-3)	3	1	1	1	1
22:5(n-3)	4	1	1	1	1
22:6(n-3)	5	2	1	1	1

Table 2.—Weight percent composition of fatty acids from commercial Atlantic coast menhaden oils[1].

	1982 (N=13)			1983 (N=10)		
Fatty acid	Mean	±S.D.	Range	Mean	±S.D.	Range
14:0	9.2	1.72	6.6-12.3	8.4	1.00	6.6-10.5
15:0	0.7	0.14	0.5- 1.1	0.6	0.04	0.6- 0.7
16:0	17.6	1.83	14.3-20.4	19.2	1.59	16.3-20.8
17:0	0.8	0.24	0.6- 1.3	1.1	0.14	0.7- 1.3
18:0	3.2	0.39	2.5- 3.7	3.5	0.30	2.9- 4.0
14:1(n-5)	0.3	0.10	0.2- 0.4	0.3	0.05	0.3- 0.4
16:1(n-9)	0.2	0.10	0.2- 0.3	0.2	0.02	0.2- 0.2
16:1(n-7)	11.0	2.37	7.5-14.8	10.1	1.70	7.7-13.4
18:1(n-9)	6.6	1.08	3.9- 8.5	6.8	0.90	5.4- 8.1
18:1(n-7)	3.0	0.28	2.6- 3.4	3.0	0.24	2.6- 3.5
20:1(n-9)	0.9	0.20	0.5- 1.4	0.9	0.17	0.7- 1.2
16:2(n-4)	1.4	0.33	0.9- 2.0	1.4	0.24	1.2- 1.9
18:2(n-6)	1.3	0.20	1.0- 1.6	1.4	0.11	1.2- 1.6
16:3(n-4)	1.7	0.72	0.9- 3.0	1.5	0.20	1.3- 1.9
18:3(n-6)	0.4	0.20	0.2- 0.7	0.3	0.04	0.2- 0.4
18:3(n-3)	1.1	0.39	0.5- 1.7	1.2	0.24	0.8- 1.5
16:4(n-1)	1.2	0.47	0.5- 2.1	1.2	0.40	0.7- 1.9
18:4(n-3)	3.2	1.04	1.5- 4.6	3.3	0.35	2.9- 3.9
20:4(n-6)	1.0	0.41	0.6- 2.1	0.7	0.09	0.6- 0.9
20:4(n-3)	1.4	0.33	0.8- 2.2	1.4	0.10	1.3- 1.6
20:5(n-3)	14.5	1.59	12.3-17.1	14.8	1.68	12.9-18.1
21:5(n-3)	0.7	0.10	0.6- 0.8	0.6	0.04	0.5- 0.7
22:5(n-6)	0.4	0.10	0.3- 0.5	0.2	0.01	0.1- 0.2
22:5(n-3)	2.1	0.24	1.9- 2.7	2.1	0.08	2.0- 2.3
22:6(n-3)	9.5	3.21	4.5-14.5	10.6	1.83	7.3-13.1

[1]Fatty acids not listed but present at <0.2 percent include 20:0, 20:1(n-11), 20:1(n-7), 20:2(n-6), 20:3(n-6), 20:3(n-3), 22:0, 22:1(n-11), 22:1(n-9), and 22:4(n-6).

Table 3.—Weight percent composition of fatty acids from commercial Gulf coast menhaden oils[1].

	1982 (N=52)			1983 (N=53)		
Fatty acid	Mean	±S.D.	Range	Mean	±S.D.	Range
14:0	9.2	0.57	7.9-11.1	8.9	0.43	7.8-10.0
15:0	0.6	0.10	0.4- 0.8	0.6	0.08	0.4- 0.8
16:0	19.8	1.17	16.9-22.8	20.3	1.06	17.7-22.4
17:0	0.8	0.20	0.3- 1.1	0.9	0.12	0.5- 1.0
18:0	3.4	0.33	2.7- 4.3	3.5	0.22	2.9- 3.9
14:1(n-5)	0.2	0.10	0.1- 0.4	0.2	0.04	0.1- 0.3
16:1(n-9)	0.2	0.10	0.2- 0.3	0.2	0.02	0.2- 0.3
16:1(n-7)	11.7	0.87	10.3-14.5	12.0	0.50	11.0-13.9
18:1(n-9)	8.2	1.62	3.9-11.3	8.7	1.31	6.5-12.3
18:1(n-7)	3.0	0.17	2.6- 3.2	3.1	0.09	2.8- 3.3
20:1(n-9)	1.2	0.36	0.5- 1.8	1.3	0.22	0.9- 1.9
16:2(n-4)	1.7	0.20	1.3- 2.2	2.0	0.20	1.7- 2.6
18:2(n-6)	1.1	0.26	0.7- 1.7	0.9	0.15	0.6- 1.2
16:3(n-4)	2.1	0.26	1.5- 2.8	2.5	0.20	2.2- 3.1
18:3(n-6)	0.6	0.10	0.3- 0.8	0.3	0.02	0.2- 0.3
18:3(n-3)	0.8	0.20	0.4- 1.2	0.9	0.20	0.4- 1.2
16:4(n-1)	1.1	0.44	0.4- 2.1	1.1	0.48	0.4- 2.1
18:4(n-3)	2.1	0.26	1.5- 2.8	2.1	0.20	1.6- 2.6
20:4(n-6)	1.0	0.26	0.5- 2.1	1.1	0.22	0.5- 1.4
20:4(n-3)	1.2	0.10	0.8- 2.0	1.1	0.08	0.9- 1.3
20:5(n-3)	13.5	1.26	11.4-17.7	13.3	0.86	11.7-15.8
21:5(n-3)	0.7	0.10	0.5- 0.9	0.6	0.01	0.5- 0.7
22:5(n-6)	0.3	0.10	0.1- 0.5	0.4	0.15	0.2- 0.7
22:5(n-3)	2.3	0.32	1.7- 3.0	2.2	0.33	1.5- 2.9
22:6(n-3)	7.0	1.38	4.2-10.6	6.6	1.32	4.2- 8.2

[1]Fatty acids not listed but present at <0.2 percent include 20:0, 20:1(n-11), 20:1(n-7), 20:2(n-6), 20:3(n-6), 20:3(n-3), 22:0, 22:1(n-11), 22:1(n-9), and 22:4(n-6).

of 10 selected fatty acids in 1982 and 1983 Gulf coast oils showed highly significant differences ($P \leq 0.001$) in the annual means of 16:0, 16:1(n-7)(palmitoleic acid), 18:1(n-7) (cis-vaccenic acid), and 22:5(n-3) (docosapentaenoic acid) (Table 4). No significant differences could be detected in the 1982 and 1983 annual mean percentages of 18:0 (stearic acid), 18:4(n-3) (octadecatetraenoic acid), or 20:5(n-3) (eicosapentaenoic acid). In the Atlantic oils, significant differences in annual mean percentages of the 10 fatty acids were slight or none at all.

Listed in Tables 5 and 6 are the 1982 and 1983 seasonal mean percentages of the 10 fatty acids in Atlantic and Gulf coast oils, respectively. On the Atlantic coast, the menhaden fishery begins in early June, whereas on the Gulf coast it begins in mid- to late-April. As a result, the April-May Gulf coast data were not included in ANOVA calculations since a matching data set was not available from the Atlantic coast plants. Highly significant differences ($P \leq 0.001$) were found in the seasonal mean percentages of all Gulf oil fatty acids except 14:0 ($P \leq 0.01$) (Table 4). In addition, there were significant differences ($P \leq 0.001$) in mean percentage of 18:1(n-9) (oleic acid), 18:1(n-7), and 22:6(n-3) (docosahexaenoic acid) in oils from the different plants. No differences were found in the mean percentages of 20:5(n-3) in oils produced by the nine Gulf plants. In 1982 and 1983 Atlantic oils, little or no significant differences were detected in seasonal means of the 10 fatty acids, and there were no significant differences in mean values of fatty acids in oils from the different plants. Seasonal changes in percentage of six fatty acids from 1982 and 1983 Gulf and Atlantic oils are compared in Figures 1-3.

Although the Gulf coast was not partitioned into eastern, central, and western regions for ANOVA calculations, seasonal percentages of three fatty acids in 1982 and 1983 oils, produced by the three Moss Point plants and the three Cameron plants, are illustrated in Figure 4. As indicated in Table 4, the probability of significant differences in mean annual percentages of 18:1(n-9) in the Gulf oils was low ($P \leq 0.05$), but both seasonal and geographic mean values differed very significantly ($P \leq 0.001$).

Discussion

One of the more important characteristics of a triacylglycerol (triglyceride) oil is its fatty acid composition, since this often determines feasible uses for the oil. Chemical modification of fatty

Table 4.—Statistical significance of differences in mean percentages of 1982 and 1983 menhaden oils[1].

	Fatty acid									
Year, oil source	14:0	16:0	18:0	16:1(n-7)	18:1(n-9)	18:1(n-7)	18:4	20:5	22:5	22:6
1982-1983, All oils										
Annual	***	***	**	N.S.	N.S.	*	N.S.	N.S.	*	N.S.
Seasonal	***	***	***	***	N.S.	***	N.S.	***	***	***
Geographic	N.S.	***	N.S.	***	***	*	***	***	***	***
1982-1983, Atlantic oils										
Annual	N.S.	*	*	N.S.	N.S.	N.S.	**	*	*	N.S.
Seasonal	N.S.	**	*	*	N.S.	*	N.S.	**	*	*
Plant location	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1982-1983, Gulf oils										
Annual	**	***	N.S.	***	*	***	N.S.	N.S.	***	**
Seasonal	**	***	***	***	***	***	***	***	***	***
Plant location	N.S.	*	**	N.S.	***	***	*	N.S.	**	***
1982, All oils										
Seasonal	***	***	***	***	N.S.	***	N.S.	***	***	**
Geographic	N.S.	***	*	*	***	N.S.	***	***	***	***
1983, All oils										
Seasonal	***	***	***	***	N.S.	***	***	***	**	***
Geographic	***	***	N.S.	***	***	***	***	***	N.S.	***

[1]*** = $P \leq 0.001$, ** = $P \leq 0.01$, * = $P \leq 0.05$, N.S. = Not significant.

Table 5.—Seasonal differences in mean percentages of biochemically important fatty acids in Atlantic coast menhaden oils.

	June				July				August				September				October			
	1982 (3 samples)		1983 (2 samples)		1982 (3 samples)		1983 (2 samples)		1982 (2 samples)		1983 (2 samples)		1982 (2 samples)		1983 (2 samples)		1982 (3 samples)		1983 (3 samples)	
Fatty acid	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.	Mean	±S.D.
14:0	10.8	1.59	10.0	0.78	10.0	0.72	8.0	0.49	8.3	0.42	7.5	1.06	9.0	3.04	8.3	0.28	7.6	0.86	8.3	0.42
16:0	15.2	1.12	16.4	0.14	16.9	1.26	18.9	0.49	18.1	0.28	20.5	0.21	19.8	0.85	20.4	0.49	18.9	0.92	19.9	0.28
18:0	2.8	0.46	3.1	0.07	3.1	0.21	3.6	0.21	3.7	0.07	3.9	0.07	3.5	0.35	3.7	0.04	3.5	0.12	3.7	0.07
16:1(n-7)	13.2	0.65	13.1	0.28	12.5	2.21	10.0	1.06	9.2	0.14	8.3	0.85	10.2	3.61	9.5	0.07	9.1	1.76	9.7	0.07
18:1(n-9)	6.6	0.47	6.1	0.28	7.0	0.91	6.5	0.35	7.1	0.14	6.7	1.63	5.1	1.63	6.9	0.63	7.2	1.25	8.1	0.07
18:1(n-7)	3.3	0.06	3.4	0.14	3.2	0.10	3.0	0.14	3.0	0.07	2.8	0.07	2.7	0.14	2.9	0.07	2.8	0.29	2.9	0.01
18:4(n-3)	3.3	1.39	3.2	0.07	2.9	0.92	3.8	0.21	3.3	0.00	3.8	0.02	3.1	2.19	3.2	0.07	3.4	1.22	3.0	0.07
20:5(n-3)	16.1	0.56	17.8	0.34	15.1	1.01	14.7	0.85	13.0	0.28	13.3	0.42	14.7	3.25	13.9	0.78	13.4	0.76	14.6	0.49
22:5(n-3)	1.9	0.06	2.1	0.04	2.0	0.06	2.1	0.05	2.2	0.00	2.2	0.07	2.4	0.49	2.3	0.07	2.4	0.21	2.2	0.07
22:6(n-3)	6.9	1.15	7.8	0.28	7.7	2.82	11.4	1.84	12.2	0.42	12.8	0.35	10.3	5.94	11.3	0.07	11.7	2.75	9.7	0.14

Table 6.—Seasonal differences in mean percentages of biochemically important fatty acids in Gulf coast menhaden oils.

Fatty acid	April-May 1982 (9 samples) Mean	±S.D.	April-May 1983 (9 samples) Mean	±S.D.	June 1982 (9 samples) Mean	±S.D.	June 1983 (9 samples) Mean	±S.D.	July 1982 (9 samples) Mean	±S.D.	July 1983 (9 samples) Mean	±S.D.	August 1982 (9 samples) Mean	±S.D.	August 1983 (9 samples) Mean	±S.D.	September 1982 (8 samples) Mean	±S.D.	September 1983 (9 samples) Mean	±S.D.	October 1982 (7 samples) Mean	±S.D.	October 1983 (8 samples) Mean	±S.D.
14:0	9.4	0.59	9.0	0.44	9.4	0.27	9.0	0.35	9.3	0.39	8.6	0.42	9.3	0.51	8.8	0.50	8.8	0.21	8.9	0.28	8.9	0.40	9.2	0.19
16:0	18.6	1.07	19.3	0.85	19.1	0.65	19.6	0.88	19.7	0.73	20.0	0.66	20.6	0.86	20.9	0.80	20.8	0.99	21.1	0.74	20.6	0.75	21.2	0.89
18:0	3.2	0.26	3.3	0.23	3.2	0.19	3.3	0.15	3.4	0.36	3.4	0.14	3.6	0.29	3.6	0.15	3.7	0.31	3.7	0.11	3.7	0.20	3.6	0.11
16:1(n-7)	12.7	1.07	12.2	0.81	12.2	0.58	12.2	0.63	11.7	0.47	11.9	0.32	11.5	0.40	11.8	0.23	11.0	0.37	11.8	0.27	10.7	0.26	12.0	0.27
18:1(n-9)	9.2	2.27	10.1	1.43	8.0	2.05	9.4	1.85	8.0	1.41	8.3	1.10	8.5	0.79	8.3	0.44	8.0	0.92	8.1	0.41	8.2	0.37	8.1	0.71
18:1(n-7)	3.1	0.07	3.2	0.13	3.1	0.05	3.2	0.12	3.0	0.17	3.2	0.09	3.0	0.20	3.1	0.07	2.9	0.16	3.1	0.09	2.9	0.11	3.1	0.09
18:4(n-3)	2.3	0.38	2.2	0.15	2.4	0.14	2.3	0.16	2.2	0.15	2.3	0.18	2.0	0.14	2.1	0.16	2.1	0.19	2.0	0.14	2.0	0.13	2.0	0.22
20:5(n-3)	14.7	1.28	14.4	0.71	14.1	0.85	14.0	0.78	13.7	0.67	13.3	0.45	12.7	0.75	12.5	0.29	12.7	0.97	12.7	0.33	12.9	0.62	12.8	0.88
22:5(n-3)	1.7	0.44	1.8	0.15	2.2	0.11	1.9	0.20	2.4	0.24	2.1	0.25	2.4	0.14	2.3	0.18	2.5	0.07	2.4	0.18	2.7	0.13	2.5	0.16
22:6(n-3)	5.7	1.04	5.4	0.82	7.0	1.41	6.2	1.19	7.1	1.70	7.3	0.68	7.0	1.28	7.2	0.27	7.7	1.05	7.3	0.41	7.7	1.05	6.8	0.41

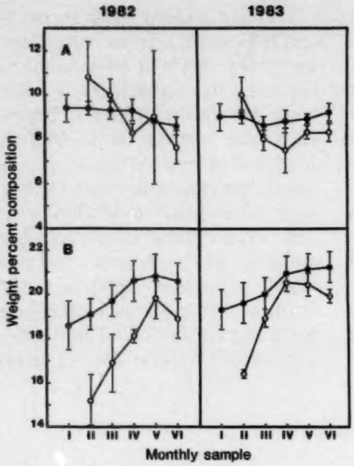

Figure 1.—Seasonal and annual percentages of 14:0 (A) and 16:0 (B) in menhaden oils from Atlantic (circles) and Gulf (dots) coast rendering plants.

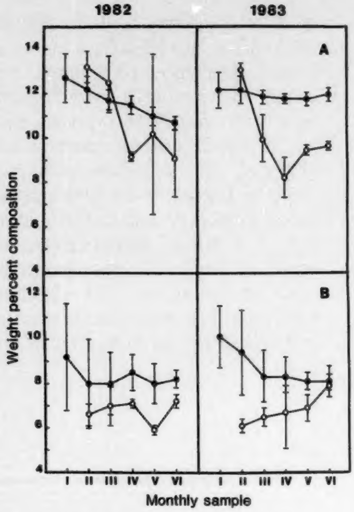

Figure 2.—Seasonal and annual percentages of 16:1(n-7) (A) and 18:1(n-9) (B) in menhaden oils from Atlantic (circles) and Gulf (dots) coast rendering plants.

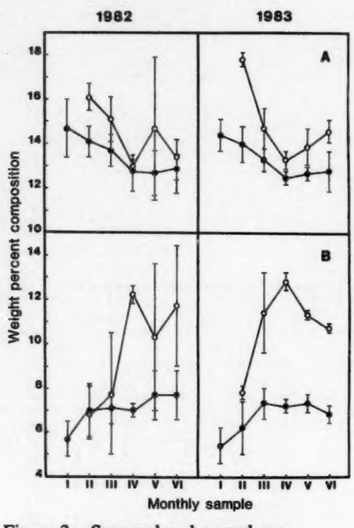

Figure 3.—Seasonal and annual percentages of 20:5(n-3) (A) and 22:6 (n-3) (B) in menhaden oils from Atlantic (circles) and Gulf (dots) coast rendering plants.

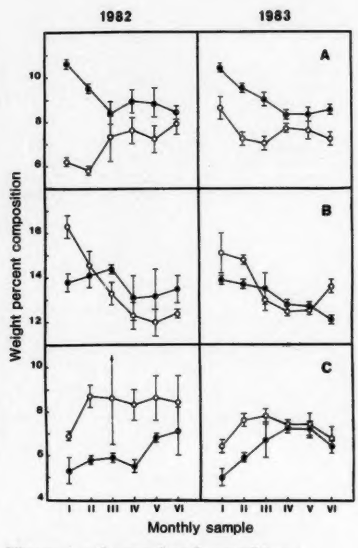

Figure 4.—Seasonal and annual percentages of 18:1(n-9) (A), 20:5(n-3) (B) and 22:6(n-3) (C) in menhaden oils from three east Gulf (circles) and three west Gulf (dots) rendering plants.

acid composition, winterization, or hydrogenation, for example, yields fats and oils with different physical properties and potential uses. Partial hydrogenation of menhaden oils and other fish oils is necessary for their incorporation into margarines or shortenings, common utilization products of fish oils in Europe and Canada for many years, although not in the United States since the early 1950's (Stansby, 1973; 1978). Oils such as herring oil that contain relatively greater percentages of saturated and monoenoic fatty acids are somewhat more suitable for partial hydrogenation than more unsaturated oils such as menhaden oil, since they require less hydrogen and catalyst for reaction. However, recent research by biochemists and physicians in a number of countries suggests that highly unsaturated marine oils, particularly those rich in 20:5(n-3), may have great potential in nutritional or therapeutic treatment of certain cardiovascular diseases (Dyerberg et al., 1978; Sanders et al., 1981; Saynor and Verel, 1980; von Lossonczy et al., 1978). Thus, since 20:5(n-3) is one of the principal fatty acids in menhaden flesh and oils, menhaden might be an excellent raw product from which pharmaceuticals or food supplements could be prepared.

The analytic methodology adopted for this study differs from that usually applied in fatty acid analyses of commercial triacylglycerol oils, such as vegetable oils which are generally homogeneous and usually not contaminated with water. Most, if not all, of the oils analyzed in this study were not homogeneous at ambient temperature, but were cloudy or contained particulate material that disappeared upon warming, suggesting the presence of stearines, a mixture of precipitated, saturated fatty acids. To eliminate the possibility of reprecipitation of stearines during drying of the warmed oils, they were not warmed but, instead, were solubilized in hexane before treatment with anhydrous Na_2SO_4 to remove water.

Ideally, GLC analyses of samples in a series should be carried out under the same instrumental methods. However, when a series is as large as that encountered in this study which required 3 months during each of 2 years to complete, modifications in chromatographic conditions may become necessary. In 1982, our isothermal analysis initially permitted baseline separation of 16:4 (n-1) and 18:0, two fatty acids of considerable interest. However, as the column aged, separation of these two components declined and it was necessary to reduce the column temperature to maintain adequate resolution. Analysis of one sample in both isothermal and temperature-programmed modes demonstrated no quantitative differences in composition of the sample.

Stansby has stressed orally (1980) and in print (1981) the importance of adequate sample size in attempting to define the fatty acid composition of oils or lipids from any species of fish. In 1982, about 800,000 metric tons (t) of menhaden were processed by Gulf coast plants; somewhat more, about 850,000 t, were processed in 1983. Assuming the catch were equally divided among the 11 plants operating on the Gulf coast, the oils from the nine participating plants would represent about 650,000 t of menhaden in 1982 and 700,000 t in 1983. Even if this assumption of equality is very inaccurate, the oils from the Gulf plants still represent a very large number of menhaden taken from Gulf waters. A similar estimate for menhaden harvested by the participating Atlantic coast plants is more difficult to derive since 6 of the 13 rendering plants on this coast are multispecies plants. However, menhaden landings for 1982 and 1983 were about 390,000 and 375,000 t, respectively, and only three plants (two in 1983) participated in the sampling program. Thus the Atlantic oils represent a far smaller sampling of the resident menhaden population than the Gulf oils.

Illustrated in Figures 1-3 are seasonal and geographic mean percentages of the six fatty acids present in greatest amount in menhaden oils. None of these fatty acids had significantly different annual mean values in 1982 and 1983 Atlantic oils, and only 16:0 and 16:1(n-7) annual means differed significantly in the Gulf oils (Table 4). However, seasonal and geographic differences were prominent. In both 1982 and 1983, the mean percentages of 16:0 (Fig. 1B) and 18:1(n-9) (Fig. 2B) were significantly greater while those of 20:5(n-3) (Fig. 3A) and 22:6(n-3) (Fig. 3B) were significantly lower in Gulf oils than in Atlantic oils. In addition, in 1983, 14:0 (Fig. 1A) and 16:1(n-7) (Fig. 2A) percentages were also significantly higher in the Gulf oils. Seasonal differences were equally prominent for these six fatty acids, and their seasonal variations were similar in 1982 and 1983 oils from the two regions. Even though menhaden oils from the Gulf contain significantly less 20:5(n-3) and 22:6(n-3) than those of the Atlantic coast, the Gulf oils yield far larger quantities of these polyunsaturates which have great potential as nutritional supplements or therapeutic agents, due to the larger menhaden catch on the Gulf coast.

In general, mean percentages of fatty acids from 1982 and 1983 Atlantic oils agreed well with data reported by Ackman (1980) on menhaden oils from the Chesapeake Bay and mid-Atlantic coastal waters. In contrast, rendered menhaden oils from Nova Scotian-caught fish contained almost twice as much 18:1 (sum of all isomers) (Ackman et al., 1981) as 1982 and 1983 Atlantic oils. Ackman et al. (1981) noted that 18:1 > 16:1 is characteristic of menhaden oils from colder Atlantic waters, whereas 16:1 > 18:1 characterizes menhaden oils from warmer waters of the Gulf (Ackman, 1980). In this study, however, the annual mean percentage of 16:1 exceeded that of 18:1 in both 1982 and 1983 Atlantic oils (Table 2).

Ackman (1980) has described menhaden oils obtained from plants located in eastern, western, and Mississippi Delta regions of the Gulf coast, although the sampling procedures were not detailed. In this comparison, no difference was found in the percentage of 18:1(n-9) in oils from the three areas (mean, 6.2; range, 6.0-6.4) (Ackman, 1980). However, during both 1982 and 1983, substantial differences in the percentage of this fatty acid were found in oils from the three Moss Point plants in the east Gulf and the three Cameron plants in the west Gulf (Fig. 4A). A three-way ANOVA of 1982 and 1983 Gulf oils (Table 4) indicated highly significant differences ($P \leqslant 0.001$) in both seasonal

and geographic means of 18:1(n-9).

The seasonal percentages of 18:1(n-9) found in each of the Gulf oils for the years 1982 and 1983 are illustrated in Figure 5. Plants located east of the Mississippi River include only the three plants in Moss Point, Miss.; those west of the River include plants in Intracoastal City and Houma, La., and three plants in Cameron, La. Only one of the plants included in this survey is located on the Mississippi Delta, at Empire, La. While the oils may be characterized as originating in east, west, or Delta region plants, the fish processed by any of the plants may have been caught in a different region of the Gulf, although economics would surely encourage harvesting in waters as near the plant as possible. Information kindly provided by W. Borden Wallace[2] supports the conclusion that there are significant differences in the composition of eastern and western Gulf menhaden oils, exemplified by 18:1(n-9) percentages, at least during the first half of the fishing season. In 1982, boats from the Empire plant fished in the western Gulf, along with boats from the Cameron plants during the April-May period. In June, however, they fished the eastern Gulf, along with boats from the Moss Point plants. In 1983, boats from the Empire plant fished exclusively in western waters during April-May and largely in the same region during June. During July and August, fishing occurred in both eastern and western waters, but during September and October, fishing was, again, in the western Gulf. As shown in Figure 5, the 18:1(n-9) content in oils from the Empire plant reflects that in oils from eastern or western plants in accordance with Mr. Wallace's description of fishing areas for boats of the Empire plant.

These geographic and seasonal differences in 18:1(n-9) percentage suggest the possibility that menhaden harvested in the Gulf may represent two biochemically different populations. However, as the menhaden is a filter-feeder whose depot fat is derived from its phytoplankton diet, it could be that the differences

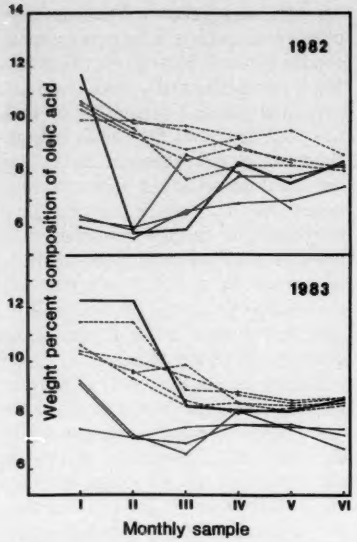

Figure 5.—A comparison of 18:1(n-9) percentages in menhaden oils produced by the plant in Empire, La. (heavy line) with those in oils from five west Gulf (dashed lines) and three east Gulf (light lines) plants.

in fatty acid composition of the menhaden oils are due to differences in phytoplankton populations of the eastern and western Gulf during the early months of the fishing season. Possibly, colder freshwater from the Mississippi River outflow during the late-spring and early-summer months creates an ecologic barrier to mixing of phytoplankton populations. On the other hand, Pristas et al. (1976) have shown that tagged menhaden, returning to inshore waters after winter offshore migration, return generally to the region from which they were originally released, indicating little mixing of fish populations during winter migration. Thus, it may be more likely that differences in phytoplankton populations in waters of their winter residence explain the observed differences in composition of east and west, Gulf-produced, early-season menhaden oils.

Conclusions

The results of this 2-year study of Atlantic- and Gulf-produced menhaden oils do not show differences of sufficient magnitude to support the concept of selective harvesting for specific utilization of the oils. While annual mean percentages of 14 component fatty acids of 1982 and 1983 Atlantic and Gulf coast menhaden oils fell within the broader ranges listed by Stansby (1981), the fact that statistically significant differences were found in the annual mean percentages of some of the fatty acids indicates that no absolute composition for menhaden oil can be predicted from year to year, over and above ranges of values. However, additional data may reveal the existence of annual cycles in fatty acid composition.

Differences in seasonal and geographic means of some fatty acids of Gulf oils, 18:1(n-9) in particular, suggest that fatty acid composition might be used as a biological tag in Gulf menhaden population studies. This application can be realized, however, only if in future studies the compositional data on the oils can be related to the specific waters from which the fish were taken. Even with cooperation of the fishing industry in providing this essential information, a multiyear study will probably be required before reliable conclusions can be drawn. Therefore, composite oil samples collected during the 1984 menhaden fishing season will again be monitored for fatty acid composition by staff of the Charleston Laboratory.

Acknowledgments

Composite oil samples were collected and provided by plant personnel of Wallace Menhaden Products, Inc., Seacoast Products, Inc., Standard Products, Inc., and Zapata Haynie Corporation. G. Seaborn and F. Van Dolah assisted with chemical and chromatographic procedures. Two-way and three-way ANOVA were calculated and interpreted by L. Ng. Valuable information and comments were provided by R. B. Chapoton, Beaufort Laboratory, NMFS, and W. B. Wallace, Wallace Menhaden Products, Inc., Mandeville, La. I thank my colleagues P. E. Bauersfeld, G. T. Seaborn, M. B. Hale, and L. Ng for their valuable criticisms of the manuscript.

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Underwater Separation of Juvenile Salmonids by Size

MICHAEL H. GESSEL, WINSTON E. FARR, and CLIFFORD W. LONG

Introduction

Improving the survival of downstream migrating Pacific salmon, *Oncorhynchus* spp., and steelhead, *Salmo gairdneri*, is a primary goal of the research being conducted on the Snake and Columbia Rivers by the National Marine Fisheries Service. Beginning in 1971, transportation of these fish around low-head hydroelectric dams has been an important part of this effort. Transportation began by collecting the migrants at Little Goose Dam on the Snake River and hauling them by truck to release sites below Bonneville Dam, the dam furthest downstream on the Columbia (Fig. 1). This program was expanded to include Lower Granite Dam on the Snake River in 1975, and McNary Dam on the Columbia River in 1978. Barging as an additional means of transportation (McCabe et al., 1979) also began in 1978.

Each of these collector dams is equipped with a fish bypass system (Matthews et al., 1977; Smith and Farr, 1975) that diverts fish from turbine intakes to raceways where they are held for later transportation. Prior to entering the raceways, the fish must pass through a separator that grades them by size. The separator is necessary because of the stress placed on fish when different sizes are held together. Steelhead for example, are generally larger as smolts than chinook salmon, *Oncorhynchus tshawytscha*, or other salmon species. Recent data from stress studies conducted at Lower Granite and Little Goose Dams on the Snake River indicate that stress levels of chinook salmon held or transported alone were significantly lower than those of chinook salmon held or transported with steelhead[1]. Not only are most of the larger steelhead separated from the smaller salmon, but other large fish and floating debris are removed from the system and returned to the river.

Separation was originally accomplished by a dry-type separator (Fig. 2).

ABSTRACT—Juvenile salmonids collected at dams on the Snake and Columbia Rivers require separation by size prior to transportation. A method of separating most of the smaller downstream migrating juvenile Pacific salmon, Oncorhynchus *spp., from the larger steelhead,* Salmo gairdneri, *at hydroelectric dams is described. The device utilizes behavioral responses that allow fish to remain in water during the separation process. This system is presently being installed at collector dams on the Columbia and Snake River.*

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[1]D. L. Park, G. M. Matthews, T. E. Ruehle, J. R. Smith, J. R. Harmon, B. H. Monk, and S. Achord. 1983. Evaluation of transportation and related research on Columbia and Snake Rivers, 1982. Unpubl. manuscr., 47 p., on file at the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prep. for U.S. Army Corps of Engineers, Portland, Oregon, under Contract DACW68-78-C-0051.)

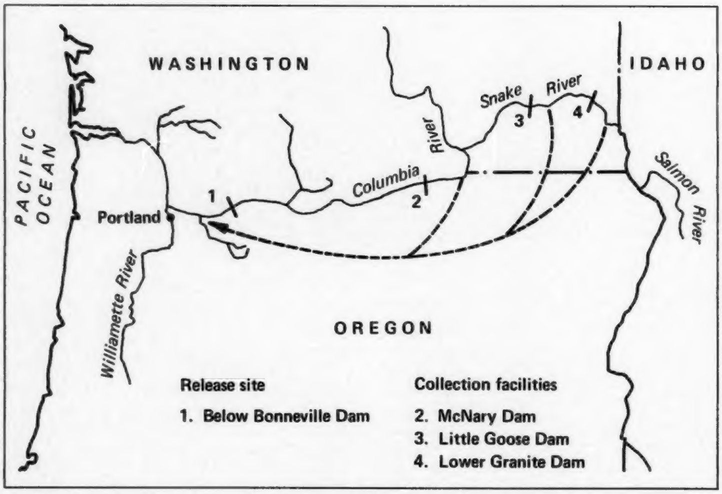

Figure 1.—Locations of fish collection facilities, transportation route, and release site.

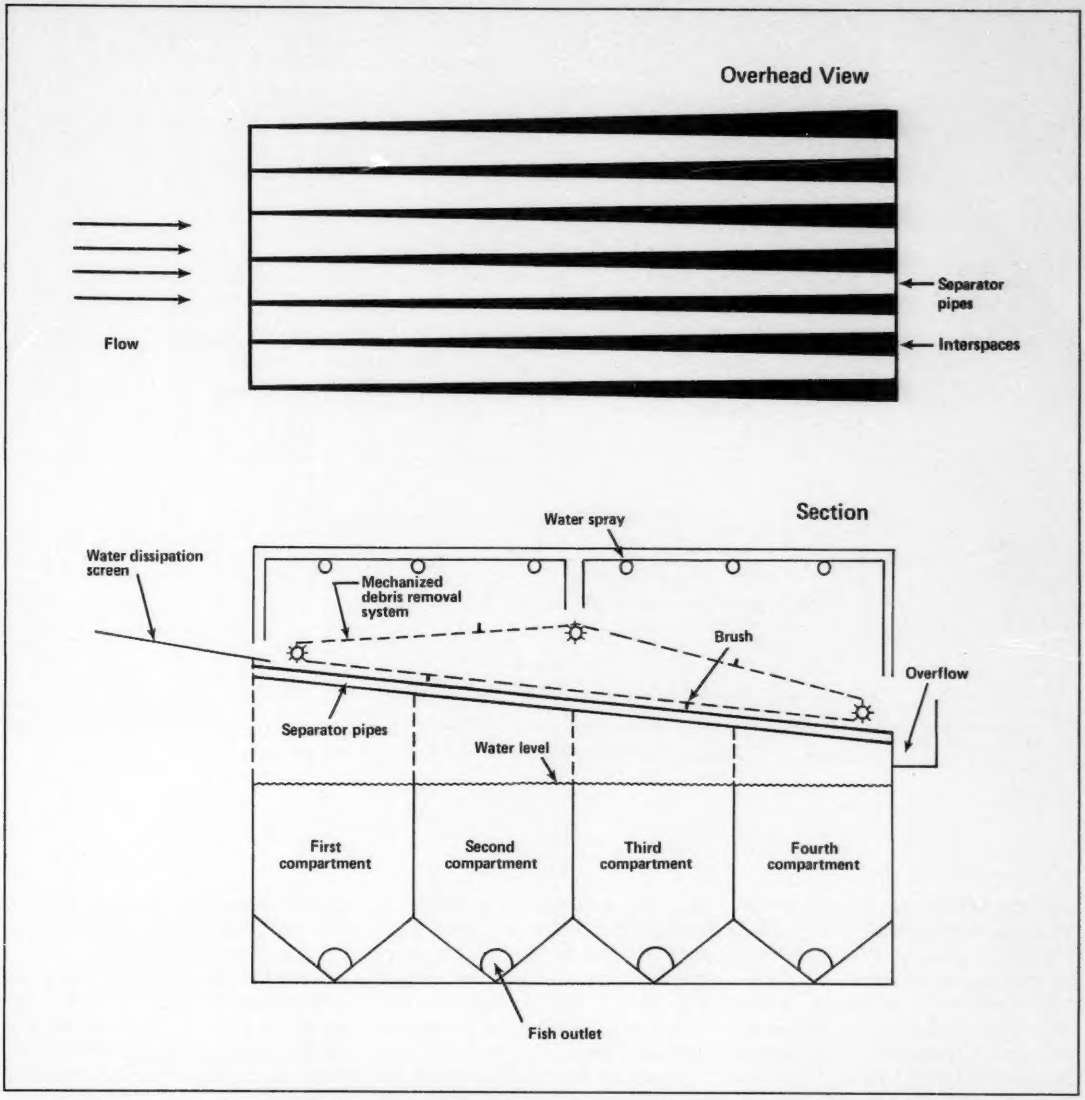

Figure 2.—Side view of dry-type separators at collection facilities prior to 1982.

These early models employed sloping pipes which fanned out so that the spaces between the pipes gradually increased. Fish separated simply by falling through the gaps formed by the diverging pipes, with the smallest fish entering the first compartment, slightly larger fish entering the next compartment, and so on. A fine spray of water was directed onto the pipes from above to aid movement of fish. Large fish and debris remained on top of the pipes to ultimately fall into a channel leading back to the river. A mechanized brush system was employed to aid movement of the large fish and debris.

Although effective as a separator, the dry-type separator was believed to cause its own stress by keeping the fish out of water during the separation process. The system also required constant attention

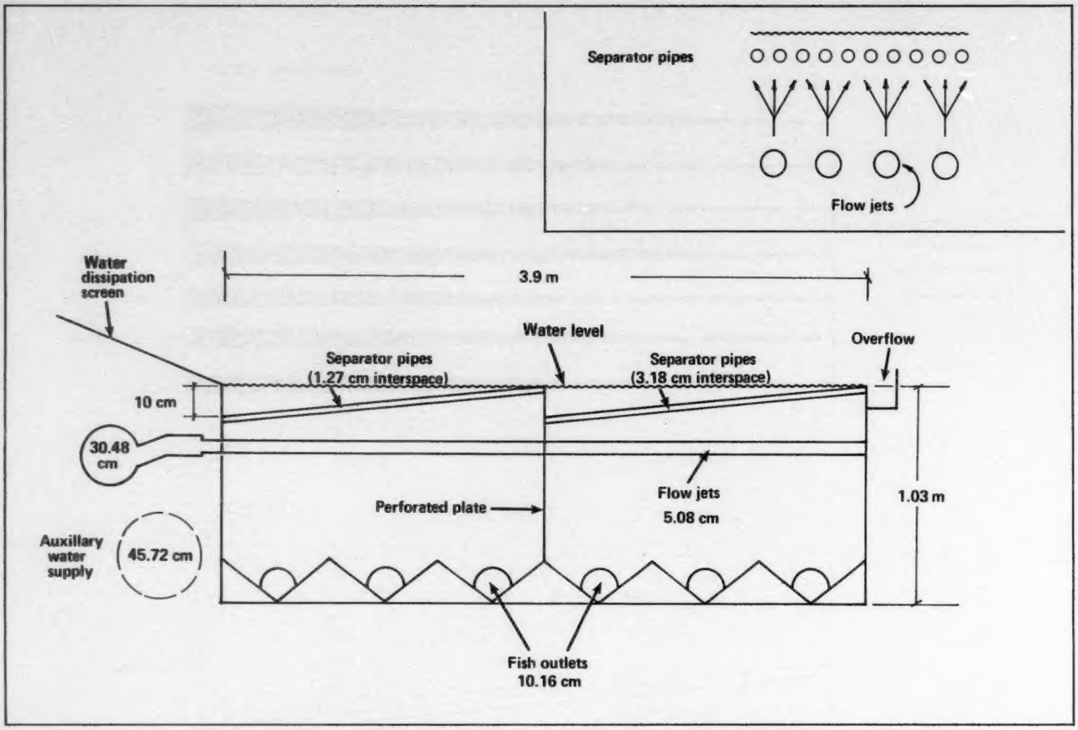

Figure 3.—Side view of prototype wet separator at Little Goose Dam, 1981.

to prevent debris from wedging between the separator pipes and possibly trapping fish. To alleviate stress on the fish, we developed a device for separating them underwater (wet-type). Initial model studies at Lower Granite Dam in 1980 were followed by tests of a prototype at Little Goose Dam in 1981. This report describes the wet separator and the results obtained during the model studies and tests.

Design and Evaluation of the Wet Separator

The prototype wet separator is illustrated in Figures 3 and 4. Two observed reactions of smolting salmonids were considered in its design: Their normal response to orient into a water flow and their tendency to sound, or dive, as an avoidance reaction. The stimulus for the first reaction is created by water jets flowing from holes in plastic pipes placed beneath the grid of submerged separator pipes in each compartment (Fig. 3 inset). This configuration produces an attraction flow toward the separator pipes.

Fingerlings moving through the bypass system enter the separator compartments at the surface after moving down an inclined screen. Their response to swim into the flow from the water jets, as well as their tendency to sound, allows smaller fish to pass volitionally through the spaces between the first set of separator pipes. Larger fish tend to move along these pipes and eventually enter the next compartment which has wider pipe spacing. If the fish are too large to pass through the pipes in the second compartment, they pass over the end of the separator and return to the river or, if desired, they can be diverted into a collection raceway.

Water flowing up from the jets tends to keep debris from accumulating on the separation pipes. It also contributes to the flow required to move floating debris along the surface of one compartment to the next and eventually off the end of the separator.

Individual pipes, each with air-operated gate valves and a maximum head of 60.96 cm (24 inches), supply water to the flow jets and the auxiliary water supply to the compartments. Flow jets consist of 0.476 cm (3/16-inch) holes at 10.16 cm (4-inch) centers in the top of 5.08 cm (2-inch) diameter pipes. These pipes are set at 15.24 cm (6-inch) intervals across the width of each compartment.

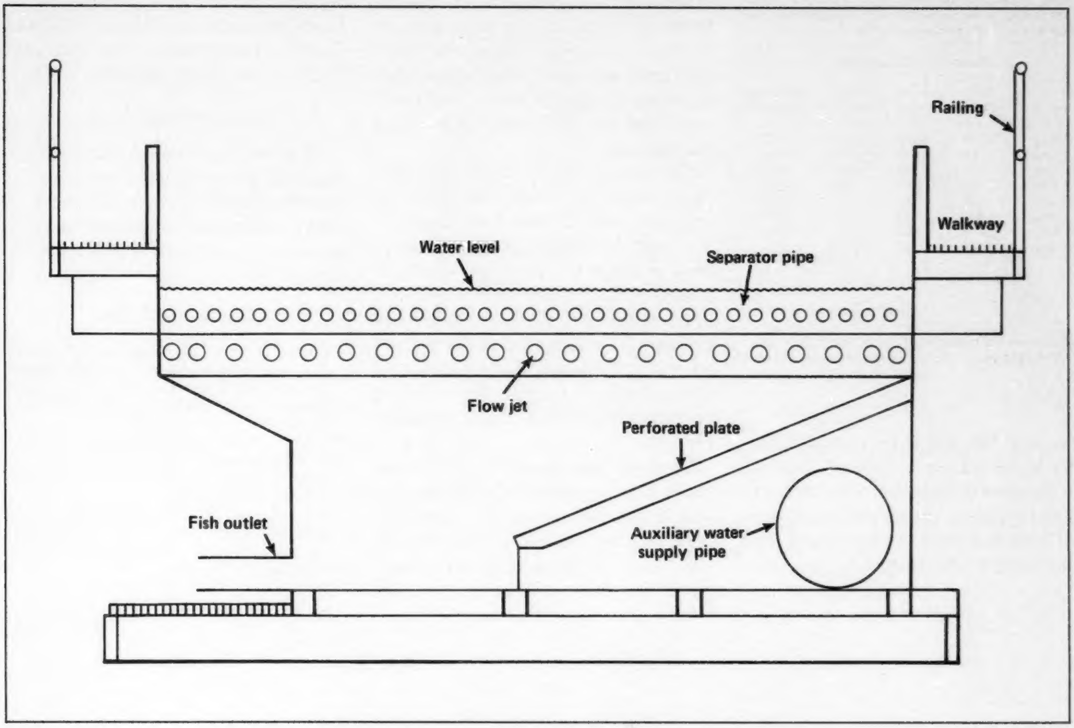

Figure 4.—End view of prototype wet separator at Little Goose Dam, 1981.

Separator pipes are metal tubes covered with plastic for smoothness (overall outside diameter = 2.22 cm or ⅞-inch). Initially, the interspace was 1.59 cm (⅝ inch) in the first compartment and 3.175 cm (1¼-inches) in the second. Later the interspace in the first compartment was reduced to 1.27 cm (½ inch) to minimize the numbers of small steelhead in the first compartment. Spacers are used to maintain gap size. Each grid of separator pipes is adjustable vertically to achieve the desired slope and water depth at the downstream end. Submergence ranged from about 10 cm at the upstream end of the separator pipes to approximately 1 cm at the downstream end.

Evaluation of both the model and prototype separators used river run fish passing through the fingerling bypasses and was based on counts of juvenile chinook salmon and steelhead observed in the two hoppers. There was effective separation in the model studies conducted at Lower Granite Dam, but separation with the prototype at Little Goose Dam was less effective.

At Lower Granite Dam, 90 percent of the smaller chinook salmon went into the first compartment and 88 percent of the steelhead into the second compartment[2]. During these tests, the quantity of water from the dissipation screens and flow jets remained constant, and the auxiliary water supply was adjusted so that a uniform flow occurred along the surface of the separator and off the downstream end.

At Little Goose Dam, correct separation of chinook salmon into the first compartment of the prototype separator averaged only 73 percent (range 60-82 percent) (Table 1). Lack of adequate control of the water flow into the prototype separator resulted in surges of water that carried chinook salmon beyond the first compartment and appeared to be the main reason for the poor separation. The prototype separator was actually part of the fish collection system at Little Goose Dam, and its water came from the upwell that dissipated energy from the bypass pipe

[2]D. L. Park, J. R. Smith, G. M. Matthews, T. E. Ruehle, J. R. Harmon, S. Achord, B. H. Monk, and M. H. Gessel. 1982. Transportation operations and research on the Snake and Columbia Rivers, 1981. Unpubl. manuscr., 34 p., on file at the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. (Prep. for U.S. Army Corps of Engineers, Portland, Oregon, under Contract DACW68-78-C-0051.)

Table 1.—Numbers and percentages of juvenile chinook salmon that were separated with the prototype wet separator at Little Goose Dam, 1981.

	Number of fish collected			
Date	Total (24 h)	Second hopper	First hopper	Percentage separation
2 May	25,444	5,772	19,672	77.3
4 May	15,086	5,174	9.912	65.7
11 May	3,527	1,266	2,261	64.1
12 May	1,168	201	967	82.8
13 May	1,389	555	834	60.0
18 May	1,954	649	1,305	66.8
19 May[1]	2,472	485	1,987	80.4
20 May[1]	3,321	642	2,679	80.7
Total	54,361	14,744	39,617	
			Grand average =	72.9

[1]Gap size in first hopper was reduced from 1.59 to 1.27 cm to minimize numbers of small steelhead in the first hopper.

carrying fish and water from the forebay to the tailrace of the dam. Because of the short distance from the lower end of the bypass to the upwell, it was very difficult to smooth out flows, and there was considerable surging in the upwell that resulted in variable water volumes being delivered to the separator. At times, the dissipator screen and separator pipes were nearly dry, and at other times heavy surges of water carried both small and large fish completely across the separator.

Fish collection facilities at Little Goose Dam are being redesigned and relocated farther away from the dam. The new facilities will be similar to those at Lower Granite Dam with better control of water entering the separator. The better control should result in more uniform flows along the surface of the separator; therefore, the separation of chinook salmon from steelhead should be more effective than that measured in 1981.

Because of the importance of reducing stress on young salmon and the demonstrated potential of the wet separator, fishery agencies have requested that the U.S. Army Corps of Engineers incorporate effective wet separators in the fingerling collection systems at Lower Granite, Little Goose, and McNary Dams as quickly as possible.

Acknowledgments

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Relationship of Sea Surface Temperature Isotherm Patterns off Northwestern Mexico to the Catch of Striped Marlin, *Tetrapturus audax*, off Southern California

JAMES L. SQUIRE, Jr.

Introduction

The relationship of sea surface temperatures to the availability of striped marlin, *Tetrapturus audax*, off southern California has interested both fishery researchers and recreational billfish fishermen. The establishment of a reasonable correspondence would provide an indicator of variations in catch resulting from anomalous environmental conditions.

Uda (1957) outlined the basic biological principles of the association between the environment, as represented by one parameter, sea surface temperature (SST), to the catch of tunas, Scombridae; and billfishes, Istiophoridae. In his paper, he discussed some of the principles of fish distribution for such larger pelagics as tunas and billfishes, including the one which states that "marine organisms are distributed according to the variable environment (hydrobiological) conditions which they require for successful development." This paper describes one such association between the distribution of striped marlin and sea surface temperature.

Many researchers have reviewed the migration of pelagic species off the North American west coast (yellowtail, *Seriola lalandei*; Pacific bonito, *Sarda chiliensis*; Pacific barracuda, *Sphyraena argentea*; white seabass, *Atractoscion nobilis*; and skipjack tuna, *Euthynnus pelamis*) into more northern latitudes during years of anomalous warm sea surface temperatures (Hubbs and Schultz, 1929; Walford, 1931; Radovich, 1961). The number of studies comparing the catches of coastal northeast Pacific pelagic species to SST changes is limited and the more recent ones are by Radovich (1961, 1975) and Squire (1982).

Several studies relate striped marlin catch to SST. Squire (1974) made a comparison of striped marlin catch rates in southern California from 1963 through 1970 for periods with either continuous or discontinuous 68°F (20.0°C) and 70°F (21.1°C) isotherm extensions into the southern California area from the south or southwest. Bimonthly temperature charts produced by the NMFS Southwest Fisheries Center, La Jolla, Calif., were used in the 1963-70 analysis. The current analysis extends the hypothesis which was first described in the 1974 study. In that study, Squire speculated that the continuity of isotherm patterns crossing the Pacific Ocean from the west and recurving northward into southern California waters may have a greater influence on the catch of striped marlin than sea surface temperature observed in fishing areas off southern California.

SST Climatology vs. Striped Marlin Catch

Uda (1957) provided a range of sea surface temperatures for a number of oceanic pelagic species of tunas and billfishes, including those for striped marlin. Optimum SST's for striped marlin, determined from commercial longline catch data, ranged from 18.5°C (64.4°F) to 24°C (75.1°F), with a minimum and maximum range of temperature from 16°C (60.8°F) to 29°C (84.2°F).

Studies of SST associated with catch of striped marlin off southern California (catch temperature) in the early 1970's were made by Squire (1974) and Talbot and Wares (1975). These studies used SST measurements from airborne infrared equipment or nearshore and shipboard measurements, and the striped marlin catch off southern California as recorded by the major billfish clubs. Striped marlin catch data for both studies were obtained from the records of one or more of the following organizations: The Tuna Club, Avalon, Catalina Island, Calif.; Balboa Angling Club, Balboa, Calif.; and The Marlin Club, San Diego, Calif.

Mean catch-temperature for striped marlin landed at San Diego was calculated by Squire (1974) based on temperature data derived from monthly airborne infrared SST surveys of southern California waters in 1963-68 (Squire, 1971) and catch location data for the same period obtained from records of The Marlin Club, San Diego, Calif. Catch-temperature for a sample size of 3,595 fish ranged from 61°F (16.1°C) to 73.0°F (22.8°C) with a mean catch temperature of 67.8°F (19.9°C) and a standard deviation of 0.5°F (0.9°C). This temperature is slightly below the midpoint (69.7°F or 20.8°C) of the optimum temperature range for striped marlin as defined by Uda (1957).

In their study on striped marlin catch-temperature, Talbot and Wares (1975) used SST data recorded at Scripps Pier, located at the Scripps Institution of Oceanography, La Jolla, Calif. They made three statistical tests from the data.

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Landings of striped marlin during the month of August from 1960 through 1970 at Avalon, Balboa, and San Diego were compared with sea surface temperatures at Scripps Pier. Correlation coefficients (r^2) (Snedecor, 1956) between SST and landings were 0.39 for Avalon, 0.26 for San Diego, and 0.35 for Balboa landings. Only the correlation for Avalon landings was significant (1 percent level).

In the second approach, Talbot and Wares (1975) used mean monthly SST's determined from Scripps Pier data for June through September (1960-70) and landings at Avalon, Balboa, and San Diego. Correlation coefficients were 0.47 for Avalon, 0.39 for Balboa, and 0.50 for San Diego. Correlation with the Avalon data was significant at the 1 percent level, and with San Diego data at the 5 percent level. Balboa catch data were not significantly correlated with Scripps SST data.

In the third test, Talbot and Wares (1975) used SST data developed bimonthly from 1947 through 1966 by the National Marine Fisheries Service, La Jolla, Calif., for three areas of 2° longitude by 2° latitude off southern California. The three areas included the major striped marlin catch areas off southern California. Correlation coefficients between SST and catches for the three areas were 0.42 for Avalon, 0.42 for Balboa, and 0.32 for San Diego. None of the coefficients was significant at the 5 percent level. Based on the available data, Talbot and Wares (1975) found that only 15-25 percent of the variation in striped marlin catch was related to SST changes off southern California. In the discussion, they stated that since a small amount of variation could be attributed to SST changes, other factors were more important than local water temperatures in determining catch of striped marlin in southern California waters.

Important Fishery Characteristics

The southern California sport fishing season for striped marlin extends from late July to early November, the months of latitudinal warming. Normally, no catches are recorded for the period from December through early June. Angler catch rates in this area are 4-5 times lower than those observed about the southern tip of Baja California Sur, Mexico, where striped marlin are caught during all months of the year by both sportfishermen and commercial longliners.

High catch rates for striped marlin have been recorded by Japanese longline operations off the southern portion of the Baja California Sur, Mexico, peninsula during all months of the year. Japanese longline data from commercial and exploratory operations show low hooking rates for striped marlin west and southwest of southern California within the California Current region during all months of the year (Anonymous, 1964-80).

The results of tagging striped marlin in the recreational fishery about the southern tip of Baja California Sur, Mexico, indicate some movement from this area toward the northwest or southern California in early summer. Some of the striped marlin tagged off the east coast of the southern tip of the Baja California peninsula have been recovered off Magdalena Bay, Mexico, northwest of the southern tip of Baja California Sur, and off southern California. The precise migration route of these tagged fish is unknown; however, the relatively short period of time between tagging off Baja California Sur, Mexico, and recovery off Magdalena Bay and southern California indicate movement to the northwest during the late spring and early summer season.

Important Oceanographic Characteristics

The ocean off southern California, sometimes called the Southern California Bight, supports a major sportfishing area for striped marlin. The general boundaries of the Bight extend from Point Conception to near the northwestern border of Baja California, Mexico. The marine environment of the Bight is different from the areas along the west coast immediate to the northwest and the southeast. From studies of current patterns off southern California using drift bottles and cards by Tibby (1939), Schwartzlose (1963), Reid et al. (1958), and Squire (1977), it was determined that in the Bight a counterclockwise current pattern was sometimes evident. The southern California Bight has numerous eddies due to the effects of the chain of offshore islands.

Studies of sea surface temperature using an airborne infrared radiometer off southern California from Point Arguello to Pta. Salsipuedes, Mexico (near lat. 32°N), were conducted from 1963 to 1979 by the NMFS in cooperation with the U.S. Coast Guard (Squire, 1971). These temperature surveys covered the major fishing areas for striped marlin off southern California. During the late summer and early fall months, the period when striped marlin catches are made, temperature survey data indicate the warmest temperature to be in the Gulf of Santa Catalina. Based on catch records from 1960 to 1981, September is the month of greatest striped marlin catch in numbers. Airborne SST survey results showing a typical distribution of SST isotherms off southern California for September 1966 (from an airborne survey on 9-14-66) are shown in Figure 1. The 5-year average temperature isotherms observed in 10′ longitude by 10′ latitude areas for September airborne surveys (1963-67) are shown in Figure 2. Included in Figure 2 is an outline of the major striped marlin fishing areas off southern California.

Sea surface temperatures within the Southern California Bight are usually warmer during the summer, when compared with sea surface temperatures to the area north of Point Conception or south of the area near the U.S.-Mexico border. On many of the airborne infrared monthly charts (Squire, 1971) and the 5-year average chart, colder temperatures have been recorded (Fig. 1 and 2) denoting significant upwelling to the north and south of San Diego.

SST Isotherm Patterns and Their Relation to Catch

Talbot and Wares' (1975) study dealt with the correlation between the catch in the high catch rate areas and the sea surface temperatures at Scripps Pier as an indicator of the trend of temperature in the major fishing areas. Temperatures observed at Scripps Pier, La Jolla, Calif., were in most cases not the same

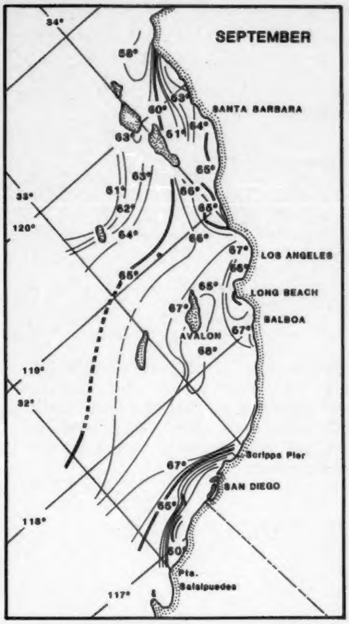

Figure 1.—Infrared sea surface temperature isotherms off southern California typical of those observed by airborne infrared sea surface surrvey during the late summer. Survey is for 14 September 1966.

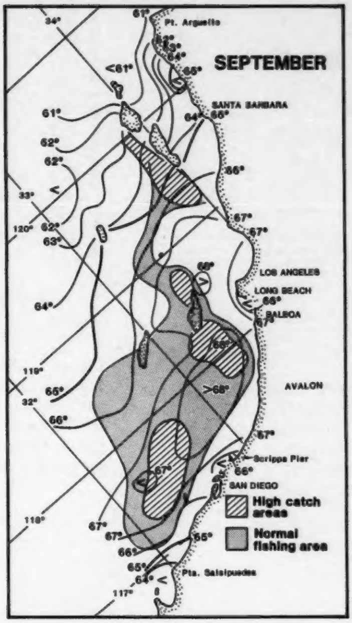

Figure 2.—Five-year mean sea temperature distribution (°F) for September airborne surveys conducted 1963-67 with outline of normal and high catch areas for striped marlin.

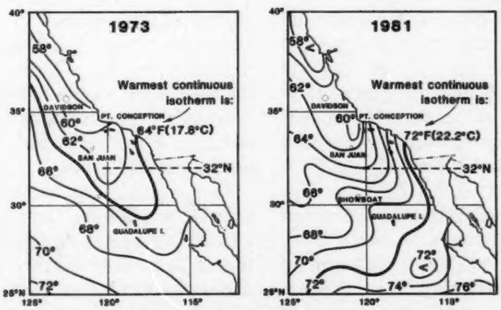

Figure 3.—Biweekly sea surface isotherm charts issued by the NMFS Southwest Fisheries Center showing examples of interception of isotherms at lat. 32°N for 16-30 September 1973 and 16-30 September 1981.

as those observed in the major fishing areas for striped marlin as shown in Figure 2. Since comparisons of SST data and catch for the southern California area have provided a rather inconclusive correlation, it was evident that striped marlin catch off southern California should be examined in relation to other environmental features. Thus, I decided to study the relationship between variation in catch and the changes in climatology of the ocean area off northwestern Baja California.

Sea surface temperature isotherm charts in 2°F (1.1°C) increments representing boundaries of areas having a mean temperature range for biweekly periods from July through November 1960-81 were used to determine the climatology of the area. These charts, which were published by the NMFS Southwest Fisheries Center, La Jolla, Calif., were examined to determine the warmest isotherm that extends continuously into southern California waters from the area south and west of a line extending off the coast at lat. 32°N (near Pta. Salsipuedes, Mexico). Examples of the warmest continuous isotherm are found on the charts for 16-30 September during 1973 and 1982 (Figure 3). That period in 1973 (Fig. 3) was characterized by low temperatures during the fishing season. For the same time period in 1981 (Fig. 3), very warm sea surface temperatures were observed. For the 1973 chart (Fig. 3) an example of the warmest continuous isotherm extending into southern California from the south or southwest at lat. 32°N is 64°F (18°C), and for the 1981 chart (Fig. 3), the warmest continuous isotherm observed was 72°F (22.2°C).

Catch data by biweekly periods from June through November 1960-81 were collected from The Marlin Club, San Diego, Calif. A total of 10,807 striped marlin were recorded during the 22-year period. Striped marlin landed during periods when isotherms of 62° - 72°F (16.7° - 22.2°C) were observed to be continuous into southern California at lat. 32°N were recorded. The frequency of striped marlin landings during different isotherm regimes for each 2-week period 16-31 July through 16-31 October 1960-81 is given in Table 1.

A linear regression was fitted in which the predictor variable was isotherm temperature (Table 1, column 1) and the criterion variable was mean number of striped marlin per 2-week period (Table 1, column 4). The results

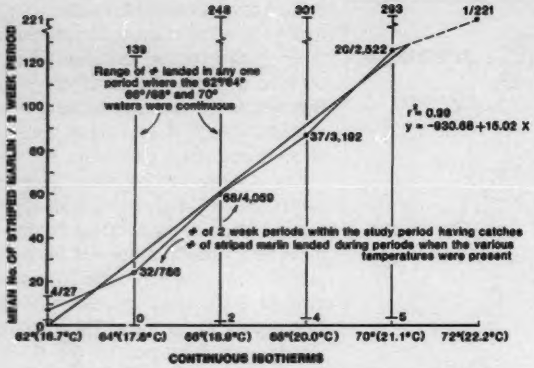

Figure 4.—Average number of striped marlin caught during 2-week periods (16-31 July through 16-31 October) and during periods when isotherms 62° - 70°F (16.7° - 21.2°C) were continuous at lat. 32°N. Data for 72°F (22.2°C) represent only one occurrence (16-30 September 1981) during the 1960-81 period. Range of catch observed within 2-week period for each isotherm is given.

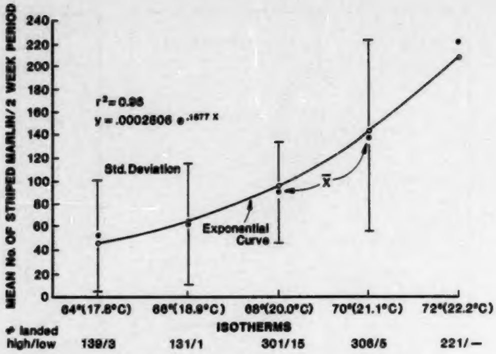

Figure 5.—Average number of striped marlin caught during 2-week periods, (1-15 August through 16-31 September) minimum and maximum number of striped marlin landed during each temperature, calculation of exponential curve and standard deviation of the mean catch observed for each temperature.

Table 1.—Number of striped marlin caught off southern California and number of periods from 16-31 July through 16-31 October when the 62°F-72°F (16.7° - 22.2°C) isotherms were the warmest isotherms continuous into southern California waters from the south, southwest, or west at lat. 32°N, 1960-81.

Isotherm °F(°C)	No. of 2-week periods when isotherms were present	Total no. of striped marlin landed	Mean no. of striped marlin per 2-week period
62°(16.7°)	4	27	6.8
64°(17.8°)	32	786	24.6
66°(18.9°)	68	4,059	59.7
68°(20.0°)	37	3,192	86.3
70°(21.1°)	20	2,522	126.1
72°(22.2°)	1	221	221.0

are presented in Figure 4. The relationship between mean catch data and the occurrence of progressively warmer isotherms is linear ($r^2 = 0.99$). However, the variation in catch (criterion) was substantial during periods when the 62° - 72°F (16.7° - 22.2°C) isotherms were continuous.

Examination of catch and temperature data of some of the larger pelagic fishes (yellowtail and Pacific bonito) off southern California by Squire (1982) indicates that the migration of fish northward from off Mexico during late spring and early summer is more related to increasing sea surface temperatures than is movement south out of southern California during the fall period of decreasing sea surface temperature. Therefore, the relationship between the catch of fish latitudinally or north-south along the coast may be more related to warming during the first part of the fishing season. To examine this possibility for striped marlin, isotherm data were plotted for the biweekly periods 1-15 August through 16-31 September (Figure 5). The curve of catch vs. temperature (Fig. 5) increases at an exponential rate, indicating that for isotherms 64°F (17.8°C) through 72°F (22.2°C) average catches increased from 46 to 208 striped marlin per period, respectively. However, the variation about the isotherm mean temperature (Fig. 5) is considerable. Therefore, results from the use of the isotherm position as a predictor of catch during any 2-week period (1-15 August – 16-31 September) could be highly variable.

Summary and Conclusions

The sport fishery catch of striped marlin off southern California during the period July through October appears to be related to sea surface temperatures observed off the Pacific coast of northwestern Mexico. Isotherms that are continuous into southern California waters from the west or southwest at 68°F (20.0°C) and above tend to be accompanied by an increase in catch; the peak continuous temperature isotherm observed in 1981 (72°F or 22.2°C) was accompanied by an increase in catch. Data also show a high variability in catch relative to any continuous isotherm during the 2-week periods. Therefore, any short-term prediction of catch based on continuous isotherm data may yield highly variable results.

Striped marlin are common to subtropical and tropical waters of lower latitudes than southern California. Sea surface temperatures in these high catch rate areas (commercial and recreational fisheries) are higher than temperatures observed to the south of the Southern California Bight. From available catch and temperature data (1960-81) and observations of the temperature range of striped marlin, it is reasonable to assume that the ocean temperatures, as defined by continuous isotherms extending into southern California from the south or southwest, never attain values

that would result in a maximum catch off southern California because catches appear to be increasing at the peak continuous isotherm recorded (72°C or 22.2°C).

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Recreational Albacore, *Thunnus alalunga*, Fishery by U.S. West Coast Commercial Passenger Fishing Vessels

DAVE HOLTS

Introduction

The commercial passenger fishing vessel (CPFV) industry along the west coast of the United States is a multimillion dollar business which contributes major economic and social benefits. The vessels include charter boats for hire by individuals or groups as well as partyboats with a first come, open seating policy. Commercial passenger fishing vessel owners and operators from the Mexican border to Puget Sound gross millions of dollars annually providing the fishing enthusiast an opportunity to "get away" and enjoy a recreational fishing experience that would not otherwise be available. Well over 1 million angler trips are logged by these west coast anglers each year. The CPFV albacore, *Thunnus alalunga*, sport catch represents from 1 to 3 percent of the North Pacific commercial albacore catch and a significant portion of the southern California recreational catch.

Background

The albacore is a valuable commercial species with annual North Pacific landings (Table 1) in excess of 75,000 metric tons (t). To the sportsman, albacore is a highly prized, migratory gamefish which contributes significantly to the southern California sport fishing industry during the summer and fall months. In northern California, Washington, and Oregon, where the coastal charter boat fishery focuses on Pacific salmon, *Oncorhynchus* spp., the albacore fishery is much less significant and the catch fluctuates considerably from year to year (Table 2).

Albacore Movements

Annual transpacific albacore migrations have been described in detail by Clemens (1961), Otsu and Uchida (1963), Clemens and Craig (1965), and Laurs and Lynn (1977). Albacore moving eastward across the North Pacific are exposed to commercial fisheries of several nations which use a variety of fishing gears. Domestic catch records indicate that commercial quantities of albacore first appear off the coast of Baja California, Mexico, and southern California in mid-June and early July. The albacore continue to move into coastal waters and northward in response to the warming of the surface waters and normally reach the offshore waters of Oregon and Washington by the end of July.

Several temperature-related factors play an important role in determining the major times and areas of albacore abundance and availability to a surface fishery along the Pacific coast. Periods of anomalous warm water, such as the El Niño events of 1959, 1972, and 1983, affect the distribution of albacore (Squire, 1983) as do seasonal variations in magnitude of coastal upwelling in the Pacific Northwest (Lane, 1965). The southern California albacore sport catch is greatest when surface waters are from 18.3° to 19.7°C (Squire, 1982); commercial fishing activity peaks along the entire coast from 17.2° to 18.9°C (Majors et al.[1]).

Rapid changes in the thermal structure are also important to the distribution and availability of albacore. Albacore tend to aggregate in the vicinity of ocean fronts. When these fronts are well developed, they may influence migration patterns and increase albacore catch rates in those areas (Laurs and Lynn, 1977). The strength and depth of the thermocline are also important to the availability of albacore. Recent tagging studies using acoustic transmitters indicate albacore swim near the bottom of the mixed layer during the day, but at sunset they begin making frequent vertical excursions near the surface which continue throughout the night (Laurs et al.[2]). Water turbidity and the amount of freshwater discharge flowing south from the Columbia River influence albacore availability off Oregon (Owen, 1968).

The Fleet

The CPFV fleets are located near major coastal metropolitan areas from which their clientele can be drawn. For albacore, they must also be located within a few hours running time of consistently good fishing grounds (Fig. 1). Consequently, the size, speed, and comfort of these vessels are important in attracting customers. Southern California passenger vessels are larger than those in northern California, Oregon, and Washington. These sport boats currently targeting on albacore are from 60 to 117 feet long and average 70 feet in length. There has also been a continuing trend in recent years to larger and more com-

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Table 1.—Catches of North Pacific albacore in metric tons, 1952-1983.

Year	Japan					Taiwan	United States				Canada	Grand total[6]
	Pole-and-line[1]	Longline[2]	Gillnet	Other gear	Total	Longline	Baitboat	Jibgoat[3,4]	Sport[5]	Total	Jigboat	
1952	41,386	26,687		237	68,710			23,843	1,373	25,216	71	93,997
1953	32,921	27,777		132	60,830			15,740	171	15,911	5	76,746
1954	28,069	20,958		38	49,065			12,246	147	12,393		61,458
1955	24,236	16,277		136	40,649			13,264	577	13,841		54,490
1956	42,810	14,341		57	57,208			18,751	482	19,233	17	76,458
1957	49,500	21,053		151	70,704			21,165	304	21,469	8	92,181
1958	22,175	18,452		124	40,731			14,855	48	14,903	74	55,708
1959	14,252	15,502		67	30,121			20,990	0	20,990	212	51,323
1960	23,156	17,369		76	42,601			20,100	557	20,657	5	63,263
1961	18,636	17,437		268	36,341		2,837	12,054	1,355	16,246	4	52,591
1962	8,729	15,764		191	24,684		1,085	19,753	1,681	22,519	1	47,204
1963	26,420	13,464		218	40,102		2,432	25,142	1,161	28,735	5	68,812
1964	23,858	15,458		319	39,635	26	3,411	18,389	824	22,624	3	62,283
1965	41,491	13,701		121	55,313	16	417	16,461	731	17,609	15	72,953
1966	22,830	25,050		585	48,465	16	1,600	15,169	588	17,357	44	65,882
1967	30,481	28,869		520	59,870	17	4,113	17,814	707	22,634	161	82,682
1968	16,597	23,961		1,109	41,667	15	4,906	20,441	951	26,298	1,028	69,008
1969	32,107	18,006		1,480	51,593	21	2,996	18,826	358	22,180	1,365	75,157
1970	24,376	15,372		956	40,704	23	4,416	21,039	822	26,277	354	67,358
1971	53,198	11,035		1,262	65,495	24	2,071	22,496	1,175	25,442	1,587	92,548
1972	60,762	12,649	1	921	74,333	25	3,750	23,600	637	27,987	3,558	105,903
1973	69,811	16,059	39	1,883	87,792	35	2,236	15,652	84	17,972	1,270	107,059
1974	73,576	13,053	224	1,065	87,918	40	4,777	20,177	94	25,048	1,207	114,213
1975	52,157	10,060	166	402	62,785	28	3,243	18,926	640	22,809	101	85,723
1976	85,336	15,896	1,070	1,394	103,696	37	2,700	16,314	713	19,724	252	123,712
1977	31,934	15,737	688	1,039	49,398	561	1,497	10,012	537	12,046	53	62,058
1978	59,877	13,061	4,029	3,209	80,176	53	950	15,700	810	17,451	23	97,712
1979	44,662	14,249	2,856	1,280	63,047	81	303	6,253	74	6,630	289	70,049
1980	46,743	14,660	2,986	1,516	65,905		382	7,599	168	8,149	212	74,349
1981[7]	27,426		17,425				784	12,280	195	13,259	200	
1982[7]							425	6,661	257	7,086	1	
1983[7]							607	9,512	87	10,119	115	

[1]Japanese pole-and-line catches include catches by research vessels.
[2]Japanese longline catches for 1952-60 exclude minor amounts taken by vessels under 20 gross tons. Longline catch weights are estimated by multiplying annual number of fish caught by average weight statistics.
[3]U.S. jigboat catches include minor amounts taken by baitboats not submitting logbooks.
[4]Jigboat catches for 1952-60 include baitboat catches.
[5]U.S. sport catch is a minimum estimate based on partial coverage.
[6]Grant totals omit unknown but minor catches by longline and pole-and-line vessels of the Republic of Korea.
[7]Figures for 1981-83 are preliminary.

Table 2.—Recreational albacore partyboat catch for all available data in number of fish and metric tons.

Year	California[1]		Oregon	Washington[2]		Total	
	No. fish	t		No. fish	t	No. fish	t
1947	11,445	84				11,445	84
1948	15,414	113				15,414	113
1949	22,692	166				22,692	166
1950	118,087	866				118,087	866
1951	75,924	557				75,924	557
1952	187,267	1,373				187,267	1,373
1953	23,363	171				23,363	171
1954	20,098	147				20,098	147
1955	78,688	577				78,688	577
1956	65,814	482				65,814	482
1957	41,540	304				41,540	304
1958	6,482	48				6,482	48
1959	39	—[3]				39	—[3]
1960	76,075	557				75,075	557
1961	184,981	1,355				184,981	1,355
1962	229,314	1,681				229,314	1,681
1963	158,372	1,161				158,372	1,161
1964	112,358	824				112,358	824
1965	99,771	731				99,771	731
1966	74,680	588				74,680	588
1967	96,497	707				96,497	707
1968	129,710	951				129,710	951
1969	48,887	358				48,887	358
1970	112,106	822				112,106	822
1971	160,361	1,175				160,361	1,175
1972	86,890	637	—[4]		—[4]	86,890	637
1973	9,858	72	—[4]	1,648	12	11,506	84
1974	12,814	94	—[4]		—[4]	12,814	94
1975	81,562	595	—[4]	5,494	45	87,056	640
1976	84,973	620	—[4]	9,566	93	94,529	713
1977	70,274	513	—[4]	4,275	24	74,549	537
1978	92,646	676	—[4]	20,137	134	112,783	810
1979	10,196	74	—[3]		—[3]	10,196	74
1980	21,309	156	—[3]	1,540	12	22,849	168
1981	26,648	195	—[3]		—[4]	26,648	195
1982	36,690	268	—[3]		—[3]	36,743	268
1983	17,161	125	—[3]		—[3]	17,161	125

[1]DFG landings converted to metric tons using 16.1 pounds average fish weight.
[2]Estimated from landing weights of locally caught commercial fish.
[3]Minimal catch reported less than 5 t.
[4]Sport catch reported but no sampling effort.

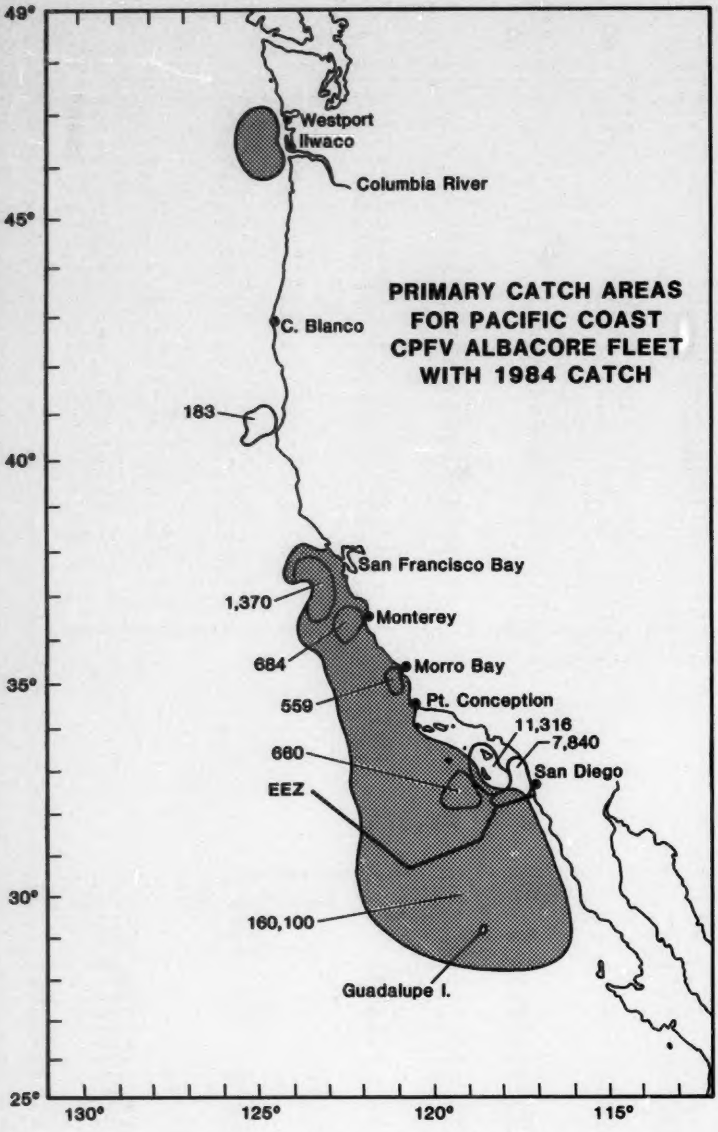

Figure 1.—Primary catch areas for the CPFV albacore fleet.

fortable vessels. In 1978, only 26 percent of the southern California vessels exceeded 65 feet and a few exceeded 100 feet, while only 5 percent of the central and northern California vessels exceed 65 feet (Gruen, Gruen, and Associates[3]).

Charter boats fishing for albacore off Oregon and Washington are temporarily drawn from the recreational Pacific salmon fishery and operate for albacore only when large quantities are close to shore. During the middle 1970's these vessels averaged 46 feet and none exceeded 65 feet in length (Lincoln and Culver, 1977). There has been continual upgrading of vessels in this fleet over the past several years; however, no large vessels have been able to move permanently into the fleet, and the size composition has not changed appreciably.

The most common fishing methods employed by the CPFV's include live bait fishing and trolling with lures and feather jigs (Dotson, 1980; Culver, 1977). Some regional variation in specific techniques has been developed to optimize local catches. For example, anglers in southern California normally troll with lures and feather jigs to locate areas of fish and then throw live anchovies in the water as chum to attract and hold the albacore at the boat while fishing with baited hooks. Jig fishing is more common in Washington and Oregon where the sportboats are usually salmon charter boats; however, many of these boats carry live bait on albacore trips. These boats are typically 25-55 feet long and carry only 6-12 passengers on 1-day trips. Albacore trips are usually scheduled only when strong local fishing is reported by commercial fishermen.

Regional Catch Information

Catch information from the CPFV fleet is collected by the individual state under whose jurisdiction the vessels operate. Each state has a survey program designed to sample the CPFV catch and to identify the economic importance of the major fisheries. The quantity and quality of statistics collected by the individual state agencies are highly variable, depending on the popularity of target species, economic importance of the species, status of targeted stocks, and political importance to a particular region.

California

Albacore, along with bluefin tuna,

[3]Gruen, Gruen, and Associates. 1979. The California commerical passenger fishing vessel and southern California live bait industries. NMFS Southwest Fish. Cent., La Jolla, Calif. Admin. Rep. LJ-79-31C, 83 p.

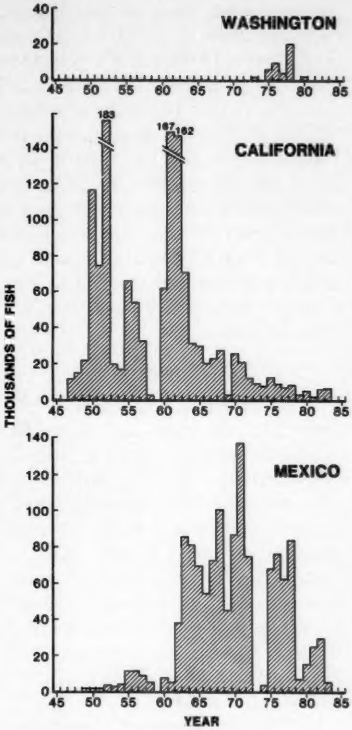

Figure 2.—Albacore catch from the waters off Mexico, California, and Washington.

Table 3.—Pacific Coast CPFV albacore catch (number of fish) and effort (C/A) by region.

	California										
	Mexico		San Diego to Pt. Conception		Pt. Conception to Oreg. border		Total		Oregon (No. of fish)	Washington	
Year	No.	C/A	No.	C/A	No.	C/A	No.	C/A		No.	C/A
1936-61	10,365	2.72	35,187	1.00	1,568	1.29	47,120	1.17			
1973	19		9,839				9,858			1,648	2.23
1974	3,850		8,964				12,814				
1975	68,296		13,266				81,562			5,494	3.40
1976	76,268		8,705				84,973			9,566	3.09
1977	62,678	1.65	6,504	1.58	1,092	0.66	70,274	1.60		4,275	1.77
1978	84,080		8,566				92,646			20,137	3.67
1979	7,260	1.50	1,021	0.61	1,915	1.01	10,196	1.21			
1980	15,657	1.36	1,290	1.93	4,362	1.08	21,309	1.32		1,540	3.06
1981	24,702	1.17	1,272	0.56	674	2.05	26,648	1.16			
1982	28,862	1.26	5,071	1.12	1,214	2.04	35,147	1.26	35	18	
1983[1]	8,968	1.84	2,990	2.05	5,203	2.21	17,161	1.96	0	0	

[1]Preliminary

Thunnus thynnus, were first reported taken in a sport fishery off Santa Catalina Island, Calif., at the turn of the century (Young, 1969). San Diego sport boats began traveling into the more productive Mexican waters (Fig. 2) in the middle 1950's for albacore, yellowtail, *Seriola lalandi*; white seabass, *Atractoscion nobilis*; Pacific barracuda, *Sphyraena argentea*; and billfish (Istiophoridae and Xiphiidae). The size, speed, and luxury of the southern California sport boats grew in response to these newly found areas off Baja California with some albacore vessels traveling as far as Guadalupe Island, 220 miles south of San Diego. The Channel Islands, nearby outer banks, and local Mexican waters all provide seasonally good albacore fishing for 1- and 2-day trips. These areas are only 30-80 miles offshore and sea conditions are normally favorable during the summer and fall months. Weather and sea conditions are commonly unfavorable north of Point Conception, Calif., because of the shorter warm-water periods and stronger prevailing winds that produce rougher seas for fishing.

The California Department of Fish and Game (CDFG) has required CPFV operators to maintain accurate records of their catch and number of passengers since 1936. Baxter and Young (1953) reported on the accuracy of some of these early records and found that albacore (also lingcod, *Ophiodon elongatus*; Pacific salmon, and yellowtail) counts were accurate over the 5-year study period (1947-51). They concluded that the high degree of accuracy was a result of the desirability of albacore, and that they were caught in relatively small numbers. By 1968, anglers frequenting southern California sport boats rated albacore the most desirable sport fish, and CPFV operators rated albacore seventh in overall importance to their business (Young, 1969).

California's historic albacore sport catch (1936-61) indicates an annual average of 41,000 albacore caught by 40,246 anglers. The catch per angler-trip (C/A) over this period averaged 1.17 with a range from 0.3 to 3.3 C/A (Clemens and Craig, 1965). Albacore effort data for 1936-61 have been merged with the data of other species taken in the same area and time period. Original records for many of these effort data are currently not available.

California anglers annually averaged 151 t (20,667 fish) between 1979 and 1983. The known number of albacore caught and the number caught per angler-trip for California, Oregon, and Washington are shown in Table 3. In southern California, albacore sportfishing dominates much of the CPFV fleet during summer and early fall. California's albacore sportfishing effort from 1979 to 1983 was conducted in the local Mexican waters; 11.3 percent occurred off southern California, and 10.6 percent occurred north of Point Conception. In contrast, records from 1936 to 1961 reveal that about 90 percent of the California effort occurred in southern California waters and 10 percent in Mexican waters, with almost no effort to the north.

Washington

The albacore CPFV fishery in Washington, which began in the early 1970's, was an offshoot of the very successful salmon charter boat fishery. The number of trips for ocean-going salmon began increasing rapidly in the late 1940's, and by early 1960's sportfishing expenditures were the single most important element in the local economy of several of Washington's coastal marine communities (Crutchfield and MacFarlane, 1968). By 1975, coastal salmon

charter boats exceeded 500,000 angler trips annually and had long since passed the effort expended by private boats (Phinney and Miller, 1977). This large, successful fishery provided the foundation for Washington's albacore charter boat fishery which began off Grays Harbor and the mouth of the Columbia River in 1970. Vessel owners found that the nearshore availability of albacore provided local saltwater anglers with good summer albacore fishing through 1978. This resource also served to boost lagging charter boat revenues brought on by decreasing salmon catches and increasing regulations.

Washington's first recreational albacore catch statistics were reported in 1973. In 1975, the Washington Department of Fisheries (WDF) began a survey to evaluate the importance of this new fishery. Catch and effort data (Table 4) were collected at the two southern coastal ports of Westport and Ilwaco (Lincoln and Culver, 1977). Survey data were not collected in 1974, although a moderately active charter boat fishery did occur. During the period for which data have been reported (1973-78), a total of 41,110 albacore weighing 308 t were landed in 13,344 angler trips, averaging 3.08 albacore per angler trip (C/A). No catch data were reported for 1979 and only 500 angler trips were reported for 1980. In both 1981 and 1982, albacore did not appear inshore. Consequently, only a few exploratory trips were scheduled and these were unproductive. The high angler catch rate observed when fish were present indicates a successful albacore sport fishery will develop any time albacore migrate within range of Washington's charter boats.

Oregon

Like Washington, the growth of Oregon's charter boat industry has long depended on various species of Pacific salmon (Wendler, 1960). Over 81,000 angler trips are logged annually for salmon; only a few have ever been reported for albacore.

Local nearshore upwelling normally displaces albacore too far offshore for Oregon's charter boats. Predominant northern winds in summer and fall transport surface waters offshore, allowing nearshore upwelling of colder waters. Lane (1965) found that, while it is a complex system, a breakdown of the normal wind patterns can result in a cessation of coastal, coldwater upwelling. As a result, albacore can move into these nearshore regions where they become available to local charter boats. Owen (1968) found that in addition to the general wind direction, the discharge of fresh water from the Columbia River into coastal and offshore areas affects albacore distribution and availability. A relatively weak upwelling was reported in 1976 (PMFC, 1977) and the Oregon Department of Fish and Wildlife (ODFW) reported that a small, opportunistic charter boat fishery for albacore developed during 1975 and 1976 (ODFW, 1977).

Interest in this sport fishery continued in 1977 and 1978 as albacore again became available 20-60 miles off Coos Bay and north to the mouth of the Columbia River. Some charter boats reported catches of up to five albacore, weighing from 15 to 20 pounds, per angler trip (PMFC, 1978). Nearshore availability has been lower since 1978 with few charter boat trips scheduled. Recent ODFW statistics indicate that only about 50 albacore were taken in 1980 and 24 in 1981. In 1982, five charter boats reported a total catch of four albacore. Oregon's sportsmen have demonstrated their interest in albacore and will certainly participate in a CPFV fishery when the fish come within 50 miles of shore.

Discussion

The commercial albacore fleets of at least five countries catch more than 70,000 t of albacore annually from the North Pacific. The U.S. Pacific coast albacore sport fishery lands less than 1 percent of the total commercial catch. Economists, however, have shown in some detail the importance of recreational fishing to regional economic growth, as well as the recreational benefits to the sportsman (Wendler, 1960; Holliday et al., 1984; Center for Natural Areas[4]).

In 1982, San Diego albacore fishermen made nearly 28,000 angler trips and spent over $1.5 million dollars on sportboat (CPFV) fees alone. The commercial value of this catch was less than $200,000. Additional revenues realized by local merchants for tackle, bait, fuel, food, and lodging have not been determined for the recreational albacore fishery, but they are significant during the season. The historic value and importance of the recreational albacore catch in northern California, Oregon, and Washington are practically undocumented. Washington's record of fishing effort in the middle 1970's was well documented, but no information exists for the periods when fishing was less than spectacular.

The tremendous fluctuation in Pacific coast CPFV catch rates is due to environmental factors that influence the

Table 4.—Washington albacore sport catch and effort reported for 1973 and 1975-78[1].

Year	No. of albacore	Total weight[2] (t)	No. of angler trips	Albacore per angler trip	No. of angler hours	Albacore per angler hour	Port sampled
1973	1,648	12.0	739	2.73			Westport
1975	5,494	45.0	1,615	3.40	10,873.9	0.51	Ilwaco
1976	947	9.2	720	1.03	5,185.1	0.16	Ilwaco
1976	8,609	83.5	2,373	3.63	21,183.0	0.41	Westport
1977	976	5.5	977	1.00	5,483.9	0.18	Ilwaco
1977	3,299	18.7	1,432	2.30	1,096.2	0.31	Westport
1978	5,748	38.2	1,796	3.20			Ilwaco
1978	14,389	95.7	3,692	3.90			Westport
Total	41,110	307.8	13,344	3.08	43,822.1	0.44	

[1]Adapted from Lincoln and Culver, 1977.
[2]Weights calculated from local commercial landings.

[4]Center for Natural Areas. 1980. Survey of partyboat passengers to summarize and analyze recreational demand for partyboat fishing in California. NMFS Southwest Fish. Cent., Admin. Rep. LJ-80-14C, 47 p.

nearshore distribution and surface availability of albacore. They normally begin moving into coastal Mexican and southern California waters in June as the waters warm to 15° - 18°C; and southern California vessels have little trouble reaching good fishing areas. North of Point Conception, Calif., albacore are present normally from mid-July through early September. Coastal upwelling of colder, deep ocean water and generally harsher oceanographic conditions combine to displace albacore beyond the range of the small, troll-type charter boats of northern California, Oregon, and Washington.

The anomalous warming periods in the eastern Pacific, known as El Niño, also disrupt the normal albacore distribution and migratory paths (Squire, 1983). This was particularly evident in 1959 when the fish did not move into southern California waters at all, and again in 1973 when the CPFV catch feel from a 5-year mean of more than 100,000 fish to less than 10,000 fish. It was during this latest period that Oregon and Washington charter boats did well on albacore around Grays Harbor and the mouth of the Columbia River. Oregon's charter boats worked these albacore schools, but effort was low compared with their other recreational fisheries and consequently was not included in their State Fisheries Census. The Washington Department of Fisheries found good activity and public interest in sustaining an albacore sport fishery, and several years of good catch and effort data were collected. Additionally, these El Niño years and those immediately following were excellent for the Oregon and Washington commercial jig boats, whose landings were well above average. The sport fishery failed in recent years due to a lack of fish within about 80 miles of shore.

The anomalous warming of 1976 was weak and short lived compared with those of 1972-73 and 1982-83 and consequently had little effect on California's recreational albacore catch. The 1982-83 El Niño was considered strong, and southern California anglers caught relatively few albacore in waters that were 1° - 3°C above normal. The warm waters attracted a record number of yellowfin, *Thunnus albacares*, and skipjack tuna, *Katsuwonus pelamis*, however, and most traditional albacore sportboats switched their effort to these tropical species by the end of July. In contrast to the 1972-73 El Niño, the recent warming did not appear to encourage the Oregon and Washington albacore charter boat fishery.

California's historic (1946-61) catch rate of 1.17 C/A and the current 3-year average of 1.32 C/A are much lower than Washington's average of 3.08 C/A. Comparing these catch rates can be misleading because effort data are not available over the same time periods, and differing modes of operation tend to enhance Washington's catch rate. These northern charter boat operators schedule albacore trips only when there are local areas of warm water or a strong commercial fishery close to shore. This selective manner of scheduling fishing trips tends to boost their success rate even though they have shorter or even nonexistent seasons. In California, albacore sport boats can usually catch enough fish to attract passengers even when they have to spend a significant amount of time scouting. Southern California's sport boats also carry more passengers per boat, some of whom may not actually fish.

More complete information describing catch statistics and the economic importance of west coast CPFV fisheries, focusing on the larger and migratory gamefish, would be useful. A specific CPFV monitoring program throughout the Pacific Northwest would help to emphasize the local importance of those recreational fisheries as well as to identify to what extent they are altered by fluctuating environmental conditions.

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Charterboat Catch and Effort From Southeastern U.S. Waters, 1983

HAROLD A. BRUSHER and BARBARA J. PALKO

Introduction

In 1982, a pilot survey was initiated at the Southeast Fisheries Center's Panama City Laboratory (SEFC-PC) using charterboat captains to obtain fishing data (Williams et al., 1984; Brusher et al., 1984). In 1983, the survey was expanded to include charterboats along the coastal and offshore waters of the southeastern United States (From North Carolina to the Florida Keys), the Gulf of Mexico (from the Florida Keys to Texas), and the U.S. Caribbean Sea (U.S. Virgin Islands and Puerto Rico).

Marine fish resources within the described areas (Fig. 1) are diverse and are exploited by recreational and commercial fishermen. Sampling within the private recreational boat fisheries group would be difficult because of the numerous docking and landing site problems and costly because of the number and categories of boats in the sampling frame. Within the charterboat fishery where recreational fishermen hire a captain and vessel for purposes of fishing, dockage and landing sites are limited, and the number of boats is usually smaller. These two factors have led researchers to select charterboat captains for obtaining marine recreational fish catch. Estimating catch per boat fishing hour (CPH) from a recreational boat fishery is less expensive than estimating total catch and effort and can provide a basis for monitoring relative abundance of species.

Personnel at the Panama City Laboratory have conducted four marine recre-

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ABSTRACT—In 1983, charterboat captains from coastal areas of the southeastern United States, Gulf of Mexico, and Caribbean Sea were contracted to provide daily catch and effort data. A total of 348,976 pelagic and demersal fish were caught during 46,921.5 hours of fishing. Species catch and catch per boat fishing hour (CPH) are presented by year, month, and location. These data are compared with the data obtained in a 1982 charterboat survey.

Major species caught by trolling were dolphin, Coryphaena hippurus*; king mackerel,* Scomberomorus cavalla*; Spanish mackerel,* S. maculatus*; little tunny,* Euthynnus alletteratus*; blue runner,* Caranx crysos*; Atlantic bonito,* Sarda sarda*; bluefish,* Pomatomus saltatrix*; great barracuda,* Sphyraena barracuda*; yellowfin tuna,* Thunnus albacares*; and blackfin tuna,* T. atlanticus*. Major species caught by methods other than trolling included red snapper,* Lutjanus campechanus*; black sea bass,* Centropristis striata*; Atlantic croaker,* Macropogonias undulatus*; sand seatrout,* Cynoscion arenarius*; seatrouts,* Cynoscion *spp.; vermillion snapper,* Rhomboplites aurorubens*; porgies, Sparidae; gray triggerfish,* Balistes capriscus*; greater amberjack,* Seriola dumerili*; and grunts, Haemulidae. CPH and species varied between survey areas.*

Figure 1.—Geographical areas used in reporting 1983 charterboat catch and effort from the southeastern United States and the U.S. Caribbean Sea.

ational boat fishing surveys: In 1975 (Brusher et al., 1977); 1976 (Brusher, n.d.[1]); 1982 (Williams et al., 1984a, Brusher et al., 1984); and 1983 (Williams et al., 1984b). The objectives of these surveys were to: 1) Evaluate and improve methods of obtaining CPH from charterboat captains throughout the southeastern United States, and 2) obtain biological information and determine geographic and seasonal availability of various recreationally caught marine species.

The 1975 and 1976 studies (Brusher et al., 1977; Brusher[1]) relied on voluntary participation by boat owners and boat captains. The results indicated that this survey method (even with monthly reward systems) was neither efficient nor reliable. The 1982 survey proved more successful because charterboat captains were contracted to provide timely catch and effort data. Also, the 1982 survey data indicated the feasibility of establishing a long-term data base concerning the availability of coastal, reef, and oceanic fishes of the southeastern United States, the Gulf of Mexico, and the U.S. Caribbean Sea. As a result, the 1983 survey was expanded in areas as well as in number of charterboats. In this report, we describe the expanded survey, highlight the results, and provide detailed CPH data for each species throughout the entire area.

Methods

Charterboats were surveyed because they are an easily identified and important component of recreational fisheries, and fishing effort is relatively consistent since charterboat captains are professional fishermen whose livelihood depends on angling success.

For this survey, charterboats were defined as a vessel available to an angler or group of anglers for which a fee is paid for the use of the captain and vessel. Letters describing our survey goals were sent to 972 charterboat captains operating in the marine waters of the southeastern United States, the Gulf of Mexico and the U.S. Caribbean Sea. We asked captains to indicate their interest in being considered as participants in the survey. From 164 positive returns, 100 were randomly selected which represented about 10 percent of the full-time charterboat captains within each of 16 areas (Fig. 1). Each captain was contracted to provide SEFC-PC with daily catch and effort data at the end of each week. Captains were paid each month only if all weekly logs for that month were received by project personnel.

The survey began on 27 March 1983 and ended on 3 December 1983, except in southeast Florida, south Florida, southwest Florida, west Florida, Louisiana, and the U.S. Caribbean Sea, where coverage extended through 31 December 1983. Some captains voluntarily submitted catch and effort data before the official starting date of 27 March, and their data have also been included in our analysis.

The cooperation we received from the majority of survey captains was excellent. Their recordkeeping was very thorough as was their promptness in submitting weekly logs. If captains failed to respond in a timely fashion, they were replaced with another captain from the original list. Twelve captains were replaced from April 1983 through November 1983.

Each captain was provided with a logbook which included log forms (Fig. 2) for reporting daily records of their catch and effort, and monthly invoice statements. A fishing week was from Sunday through Saturday and log forms (self-addressed and postpaid) were returned on Monday or Tuesday of the next week.

Upon receipt of the log form, data were documented as to date received, and each charterboat was identified by numeric code. Combinations of fishing zones were coded per the 1982 survey (Williams et al., 1984). Hours of fishing were rounded to the nearest 0.5 hour, and all fish species were assigned a numeric code. The captains were contacted by telephone to correct inaccurate or incomplete logs before the data were entered into the computer. All species were listed by the names in Robins et al. (1980). Suspected identification problems were resolved by sending FAO species identification sheets (Fischer, 1978) to captains.

After all log forms were corrected and numerically coded, data were "posted" into the SEFC-PC minicomputer to maintain a response file. After all log forms were posted, data were entered into the Burroughs[2] time-sharing system (located at the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash., verified, corrected, and then transferred to archival storage. Data analysis provided total catch and CPH. CPH was computed by dividing the total catch per species by the total boat hours of fishing.

Data can be reported by individual boats or by combined boats, by individual areas or by combined areas, by trolling or by nontrolling fishing methods, by fishing zone(s), by daily, weekly, monthly, or yearly intervals, and by any combination(s) of the above. Computer capabilities give unlimited analytical capacity to represent statistically any species or species group.

Charterboat Characteristics

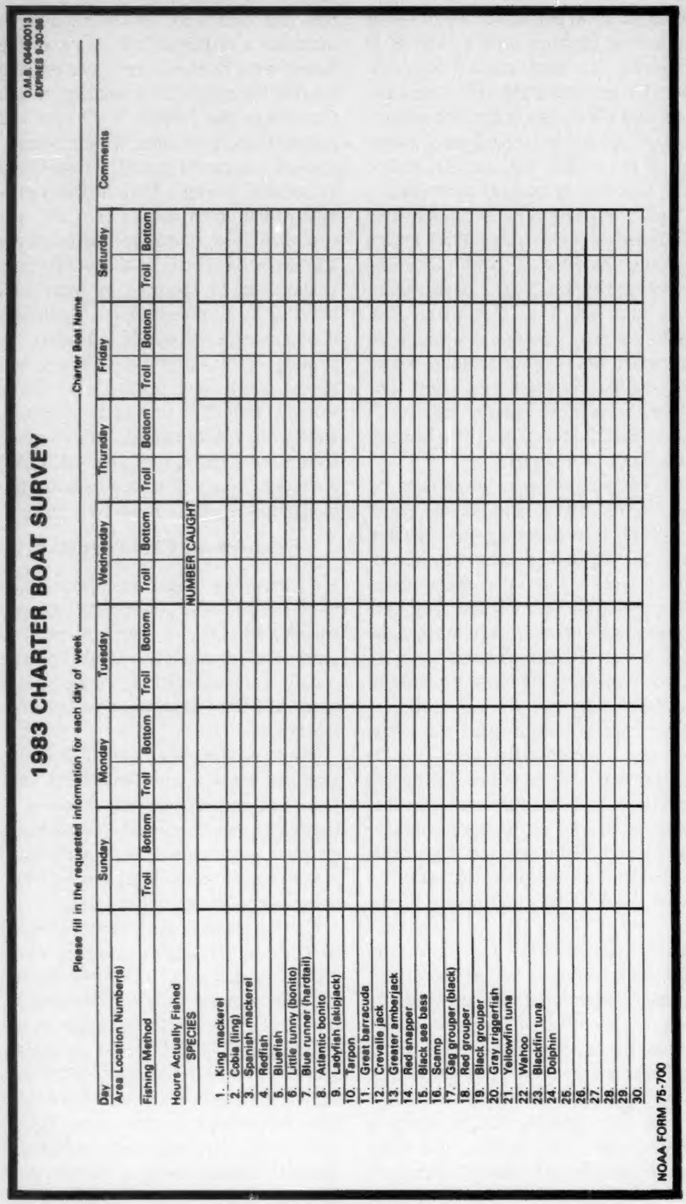
Charterboats ranged in length from 24 to 58 feet and were powered by outboard or inboard (twin or single screw) engines. Trolling boats fished 1-8 lines, but usually 4. If other fishing methods were used, 1-20 lines were fished with 4-6 being typical.

White marlin, blue marlin, dolphin, king mackerel, Spanish mackerel, sailfish, and amberjack were reported as target species when trolling, while black sea bass, seatrout, snappers, and groupers were reported as target species when using other fishing techniques.

Fishing effort in an area was affected by 1) the target species sought by charterboat clients and 2) the inshore/offshore bottom topography. For example, the 100-fathom depth is closer to the coastlines of North Carolina, southeast Florida, south Florida, northwest Florida, south Texas, and the U.S. Caribbean Sea. More boats in these areas fished for oceanic or pelagic species than did charterboats off southwest Florida, west Florida, or Louisiana. In those areas,

[1]Brusher, H. A., SEFC Panama City Laboratory NMFS, NOAA, 3500 Delwood Beach Road, Panama City, FL 32407-7499. Unpubl. data.

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.



O.M.B. 0648-0013
EXPIRES 9-30-86

1983 CHARTER BOAT SURVEY

Please fill in the requested information for each day of week ________ Charter Boat Name ________

Day	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Comments
Area Location Number(s)															
Fishing Method	Troll	Bottom	Troll	Bottom	Troll	Bottom	Troll	Bottom	Troll	Bottom	Troll	Bottom	Troll	Bottom	
Hours Actually Fished															
SPECIES	NUMBER CAUGHT														
1. King mackerel															
2. Cobia (ling)															
3. Spanish mackerel															
4. Redfish															
5. Bluefish															
6. Little tunny (bonito)															
7. Blue runner (hardtail)															
8. Atlantic bonito															
9. Ladyfish (skipjack)															
10. Tarpon															
11. Great barracuda															
12. Crevalle jack															
13. Greater amberjack															
14. Red snapper															
15. Black sea bass															
16. Scamp															
17. Gag grouper (black)															
18. Red grouper															
19. Black grouper															
20. Gray triggerfish															
21. Yellowfin tuna															
22. Wahoo															
23. Blackfin tuna															
24. Dolphin															
25.															
26.															
27.															
28.															
29.															
30.															

NOAA FORM 75-700

Figure 2.—Logform used for reporting catch and effort from the 1983 charterboat survey of southeastern United States and the U.S. Caribbean Sea.

the dominant fishing method was geared toward the capture of reef or demersal species. Off Louisiana, a technique called "fly-lining," where live bait is fished from anchored vessels was used. Trolling effort was reported from all 16 areas, and fishing effort other than trolling was reported in all areas except the U.S. Caribbean Sea.

Results

Charterboat captains reported 3,479 of the 3,503 available boat fishing weeks. Within 10 days after a fishing week the response rate (i.e., receipt of logs) was over 60 percent, within 20 days over 70 percent and by 30 days over 90 percent. In 1983, we obtained 99.3 percent of the logs for which we contracted. Captains reported fishing a total of 46,921.5 hours, of which 31,122.0 hours (66.3 percent) were spent trolling and 15,799.5 hours (33.7 percent) were spent other than trolling (Table 1). Of the reported total fishing effort, 58.3 percent was in zone 3 (waters >10 fathoms), 19.0 percent was in zone 2 (waters <10 fathoms), 9.1 percent was in zone 1 (bay or estuarine waters), and 13.6 percent was in zones 4 through 7 (combinations of zones 1, 2, and 3).

Evaluation of total fishing effort showed that along the coastal waters of the Atlantic, south Florida had the greatest total fishing effort (32.4 percent), followed by North Carolina (22.1 percent), and east Florida (16.0 percent). In the Gulf of Mexico, northwest Florida had the greatest total fishing effort (28.4 percent), followed by southwest Florida (15.9 percent), and south Texas (11.9 percent). There was general agreement between the percentage of total fishing effort in different zones reported in 1982 (Brusher et al., 1984) and this survey.

During this survey, 348,976 pelagic and demersal fish specimens were caught (Tables 2 and 3), of which 111,664, representing 84 species and species groups, were taken by trolling and 237,312, representing 107 species and species groups, were taken by other methods. Of the reported 128 taxa, 15 were caught only by trolling, and 37 only by methods other than trolling.

Table 1.—Total fishing hours by area, zone, and method of fishing during 1983 charterboat survey off southeastern United States and in the U.S. Caribbean Sea.

Area	1 Estuarine	2 Oceanic (<10 fm)	3 Oceanic (>10 fm)	4 Estuarine and oceanic (<10 fm)	5 Estuarine and oceanic (>10 fm)	6 Oceanic (all depths)	7 Estuarine and oceanic (all depths)	Total
	Hours trolling and (other fishing)							
North Carolina	270.5 (83.0)	245.5 (57.0)	3,896.5 (213.0)	16.0 (4.0)	— (—)	70.0 (18.0)	— (—)	4,498.5 (375.0)
South Carolina	— (—)	638.5 (99.0)	144.5 (72.0)	— (—)	— (—)	48.5 (249.0)	— (—)	859.5 (420.0)
Georgia	— (—)	100.5 (60.0)	69.5 (55.5)	— (—)	— (—)	10.5 (1.5)	— (—)	180.5 (117.0)
Florida (NE)	20.0 (149.5)	166.0 (43.0)	105.0 (68.0)	— (39.0)	— (—)	249.0 (3.0)	— (—)	540.0 (302.5)
Florida (E)	7.0 (1.0)	35.0 (53.5)	1,833.0 (413.5)	— (—)	— (—)	1,198.0 (3.5)	— (—)	3,073.0 (471.5)
Florida (SE)	86.0 (14.0)	115.0 (41.0)	3,258.5 (295.5)	— (—)	16.5 (1.0)	273.0 (37.0)	— (—)	3,749.0 (388.5)
Florida (S)	34.5 (130.5)	232.0 (161.5)	5,111.0 (506.5)	4.5 (240.5)	— (—)	556.5 (180.5)	— (—)	5,938.5 (1,219.5)
Florida (SW)	53.0 (2,040.5)	33.0 (1,026.0)	— (214.0)	— (104.5)	— (11.0)	— (463.5)	— (—)	86.0 (3,859.5)
Florida (W)	5.5 (776.5)	801.0 (410.0)	113.5 (223.0)	— (—)	— (—)	175.5 (7.0)	— (—)	1,095.5 (1.416.5)
Florida (NW)	323.5 (—)	1,210.0 (436.5)	1,148.0 (2,706.5)	304.0 (17.0)	— (—)	603.5 (289.0)	14.0 (—)	3,603.0 (3,449.0)
Alabama	12.0 (—)	701.0 (141.0)	69.0 (282.0)	6.0 (—)	12.0 (—)	481.5 (377.0)	— (—)	1,281.5 (800.0)
Mississippi	— (—)	733.5 (79.5)	12.0 (9.0)	— (—)	— (—)	3.0 (6.0)	— (—)	748.5 (94.5)
Louisiana	5.0 (10.0)	23.0 (20.0)	518.5 (1,868.5)	— (—)	— (5.0)	103.5 (14.0)	— (5.0)	650.0 (1,922.5)
Texas (N)	— (27.0)	164.0 (199.0)	331.5 (385.5)	— (—)	— (—)	7.0 (1.0)	— (—)	502.5 (612.5)
Texas (S)	9.0 (210.5)	820.0 (64.5)	1,638.0 (43.5)	— (31.0)	— (—)	123.5 (1.5)	— (—)	2,590.5 (351.0)
U.S. Caribbean	— (—)	— (—)	1,748.5 (—)	5.0 (—)	— (—)	— (—)	— (—)	1,753.5 (—)
Totals	826.0 (3,442.5)	6,008.0 (2,901.5)	19,997.0 (7,356.0)	335.5 (436.0)	28.5 (17.0)	3,913.0 (1,641.5)	14.0 (5.0)	31,122.0 (15,799.5)

[1]Dashes indicate no effort within this fishing zone for this area.

Table 2.—Number of each species or species group caught by trolling during 1983 charterboat survey off southeastern United States and the U.S. Caribbean Sea.

Common name	Scientific name	Total	Common name	Scientific name	Total
Dolphin	*Coryphaena hippurus*	24,047	Gray snapper	*Lutjanus griseus*	20
King mackerel	*Scomberomorus cavalla*	19,733	Lizardfishes	Synodontidae	20
Spanish mackerel	*Scomberomorus maculatus*	14,847	Bar jack	*Caranx ruber*	19
Little tunny	*Euthynnus alletteratus*	11,133	Atlantic mackerel	*Scomber scombrus*	17
Blue runner	*Caranx crysos*	9,361	Dusky shark	*Carcharhinus obscurus*	16
Atlantic bonito	*Sarda sarda*	7,065	Remoras	Echeneidae	16
Bluefish	*Pomatomus saltatrix*	4,997	Snowy grouper	*Epinephelus niveatus*	15
Great barracuda	*Sphyraena barracuda*	4,460	Scamp	*Mycteroperca phenax*	14
Yellowfin tuna	*Thunnus albacares*	4,438	Leatherjacket	*Oligoplites saurus*	14
Blackfin tuna	*Thunnus atlanticus*	2,087	Tilefishes	Malacanthidae	14
Crevalle jack	*Caranx hippos*	1,441	Red grouper	*Epinephelus morio*	12
Greater amberjack	*Seriola dumerili*	1,049	Bull shark	*Carcharhinus leucas*	11
Wahoo	*Acanthocybium solanderi*	950	Sea basses	Serranidae	11
Ladyfish	*Elops saurus*	942	Atlantic cutlassfish	*Trichiurus lepturus*	10
Red drum	*Sciaenops ocellatus*	564	Horse-eye jack	*Caranx latus*	10
Cobia	*Rachycentron canadum*	455	Silky shark	*Carcharhinus falciformis*	10
Skipjack tuna	*Euthynnus pelamis*	427	Tripletail	*Lobotes surinamensis*	10
Sailfish	*Istiophorus platypterus*	370	Flounder	*Paralichthys* sp.	9
Yellowtail snapper	*Ocyurus chrysurus*	285	Finetooth shark	*Carcharhinus isodon*	8
White marlin	*Tetrapturus albidus*	279	Menhaden	*Brevoortia* sp.	8
Cero	*Scomberomorus regalis*	248	Tigar shark	*Galeocerdo cuvieri*	7
Albacore	*Thunnus alalunga*	230	Mako	*Isurus* sp.	7
Red snapper	*Lutjanus campechanus*	203	Rainbow runner	*Elagatis bipinnulata*	6
Gray triggerfish	*Balistes capriscus*	178	Bluefin tuna	*Thunnus thynnus*	5
Sharks	Squaliformes	164	Snappers	Lutjanidae	5
Black sea bass	*Centropristis striata*	156	Almaco jack	*Seriola rivoliana*	4
Blue marlin	*Makaira nigricans*	151	Bigeye scad	*Selar crumenophthalmus*	4
Hammerhead shark	*Sphyrna* sp.	151	Houndfish	*Tylosurus crocodilus*	3
Black grouper	*Mycteroperca bonaci*	129	Sheepshead	*Archosargus probatocephalus*	3
Blacktip shark	*Carcharhinus limbatus*	124	Atlantic moonfish	*Selene setapinnis*	1
Vermilion snapper	*Rhomboplites aurorubens*	102	Atlantic spadefish	*Chaetodipterus faber*	1
Lesser amberjack	*Seriola fasciata*	81	Black drum	*Pogonias cromis*	1
Gag	*Mycteroperca microlepis*	69	Bonnethead	*Sphyrna tiburo*	1
Porgies	Sparidae	67	Cownose ray	*Rhinoptera bonasus*	1
Tarpon	*Megalops atlanticus*	56	Hardhead catfish	*Arius felis*	1
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	51	Permit	*Trachinotus falcatus*	1
Seatrout	*Cynoscion* sp.	50	Sandbar shark	*Carcharhinus plumbeus*	1
Mutton snapper	*Lutjanus analis*	48	Searobins	Triglidae	1
Lane snapper	*Lutjanus synagris*	47	Spinner shark	*Carcharhinus brevipinna*	1
Grunts	Haemulidae	36	Swordfish	*Xiphias gladius*	1
Yellow jack	*Caranx bartholomaei*	30	Sand seatrout	*Cynoscion arenarius*	1
Sand perch	*Diplectrum* sp.	24			
Bigeye tuna	*Thunnus obesus*	21	Total		111,664

Table 3.—Number of each species or species group caught by methods other than trolling during 1983 charterboat survey off southeastern United States.

Common name	Scientific name	Total	Common name	Scientific name	Total
Red snapper	*Lutjanus campechanus*	50,766	Cusk-eels	Ophidiidae	51
Black sea bass	*Centropristis striata*	36,610	Leatherjackets	Balistidae	49
Atlantic croaker	*Micropogonias undulatus*	23,714	Lesser amberjack	*Seriola fasciata*	48
Sand seatrout	*Cynoscion arenarius*	18,452	Toadfish	*Opsanus* sp.	48
Seatrouts	*Cynoscion* spp.	14,408	Gafftopsail catfish	*Bagre marinus*	38
Vermilion snapper	*Rhomboplites aurorubens*	13,477	Wrasses	Labridae	38
Porgies	Sparidae	13,247	Bigeye scad	*Selar crumenophthalmus*	34
Gray triggerfish	*Balistes capriscus*	13,114	Almaco jack	*Seriola rivoliana*	33
Greater amberjack	*Seriola dumerili*	8,093	Cero	*Scomberomorus regalis*	33
Grunts	Haemulidae	4,127	Rainbow runner	*Elagatis bipinnulata*	33
Red grouper	*Epinephelus morio*	3,831	Permit	*Trachinotus falcatus*	27
Gag	*Mycteroperca microlepis*	3,169	Palometa	*Trachinotus goodei*	24
Spotted seatrout	*Cynoscion nebulosus*	2,871	Remoras	Echeneidae	23
Gray snapper	*Lutjanus griseus*	2,283	Nurse shark	*Ginglymostoma cirratum*	18
Ladyfish	*Elops saurus*	2,245	Wahoo	*Acanthocybium solanderi*	18
Red drum	*Sciaenops ocellatus*	2,233	Blackfin tuna	*Thunnus atlanticus*	16
Bluefish	*Pomatomus saltatrix*	2,108	Puffers	Tetraodontidae	16
King mackerel	*Scomberomorus cavalla*	2,014	Yellow jack	*Caranx bartholomaei*	15
Dolphin	*Coryphaena hippurus*	1,960	Dusky shark	*Carcharhinus obscurus*	14
Yellowtail snapper	*Ocyurus chrysurus*	1,807	Lemon shark	*Negaprion brevirostris*	14
Crevalle jack	*Caranx hippos*	1,753	Sailfish	*Istiophorus platypterus*	14
Blue runner	*Caranx crysos*	1,701	Bonefish	*Albula vulpes*	13
Pinfish	*Lagodon rhomboides*	1,100	Soapfish	*Rypticus* sp.	11
Little tunny	*Euthynnus alletteratus*	1,018	Bull shark	*Carcharhinus leucas*	7
Kingfish	*Menticirrhus* sp.	974	Bonnethead	*Sphyrna tiburo*	6
Spanish mackerel	*Scomberomorus maculatus*	855	Jewfish	*Epinephelus itajara*	6
Hardhead catfish	*Arius felis*	812	Tiger shark	*Galeocerdo cuvieri*	6
Scamp	*Mycteroperca phenax*	769	Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	5
Sheepshead	*Archosargus probatocephalus*	647	Yellowfin tuna	*Thunnus albacares*	5
Lane snapper	*Lutjanus synagris*	637	Houndfish	*Tylosurus crocodilus*	4
Tarpon	*Megalops atlanticus*	605	Lizardfishes	Synodontidae	4
Cobia	*Rachycentron canadum*	554	Morays	Muraenidae	4
Sharks	Squaliformes	545	Yellowfin grouper	*Mycteroperca venenosa*	4
Sand perch	*Diplectrum* sp.	409	Atlantic moonfish	*Selene setapinnis*	3
Black grouper	*Mycteroperca bonaci*	382	Horse-eye jack	*Caranx latus*	3
Snappers	Lutjanidae	365	Lookdown	*Selene vomer*	3
Great barracuda	*Sphyraena barracuda*	363	African pompano	*Alectis ciliaris*	2
Mutton snapper	*Lutjanus analis*	284	Codfishes	Gadidae	2
Snowy grouper	*Epinephelus niveatus*	262	Sennet	*Sphyraena* sp.	2
Atlantic bonito	*Sarda sarda*	246	Spot	*Leiostomus xanthurus*	2
Silver perch	*Bairdiella chrysoura*	245	Atlantic guitarfish	*Rhinobatos lentiginosus*	1
Blacktip shark	*Carcharhinus limbatus*	209	Flyingfishes	Exocoetidae	1
Tilefishes	Malacanthidae	197	Leatherjacket	*Oligoplites saurus*	1
Flounder	*Paralichthys* sp.	181	Mako	*Isurus* sp.	1
Warsaw grouper	*Epinephelus nigritus*	142	Sand lance	*Ammodytes* sp.	1
Snook	*Centropomus* sp.	123	Sand tiger	*Odontaspis taurus*	1
Sea basses	Serranidae	122	Searobins	Triglidae	1
Black drum	*Pogonias cromis*	121	Shrimp eel	*Ophichthus gomesi*	1
Angelfishes	Pomacanthidae	119	Silky shark	*Carcharhinus falciformis*	1
Florida pompano	*Trachinotus carolinus*	83	Skates	Rajidae	1
Atlantic spadefish	*Chaetodipterus faber*	72	Skipjack tuna	*Euthynnus pelamis*	1
Hammerhead shark	*Sphyrna* sp.	65			
Tripletail	*Lobotes surinamensis*	63	Total		237,312
Stingrays	Dasyatidae	55			

Trolling produced an average of 3.6 fish per boat hour. The ten most abundantly caught fishes (areas combined) by number and percent of total trolling catch were: Dolphin, 24,047 (21.5 percent); king mackerel, 19,733 (17.7 percent); Spanish mackerel, 14,847 (13.3 percent); little tunny, 11,133 (10.0 percent); blue runner, 9,361 (8.4 percent); Atlantic bonito, 7,065 (6.3 percent); bluefish, 4,997 (4.5 percent); great barracuda, 4,460 (4.0 percent); yellowfin tuna, 4,438 (4.0 percent); and blackfin tuna, 2,087 (1.9 percent).

Fishing methods other than trolling produced an average of 15.0 fish per boat hour, with 67.4 percent of this type of fishing effort spent fishing off southwest, west, and northwest Florida, and Louisiana. The ten most abundantly caught fish (combined areas) were: Red snapper, 50,766 (21.4 percent); black sea bass, 36,610 (15.4 percent); Atlantic croaker, 23,714 (10.0 percent); sand seatrout, 18,452 (7.8 percent); unidentified seatrout, 14,408 (6.1 percent); vermilion snapper, 13,477 (5.7 percent); unidentified porgies, 13,248 (5.6 percent); gray triggerfish, 13,144 (5.5 percent); greater amberjack, 8,093 (3.4 percent); and unidentified grunts, 4,127 (1.7 percent).

Catches per boat hour and species caught by trolling varied between survey areas (Tables 4 and 5). In the U.S. south Atlantic and the U.S. Caribbean Sea, king mackerel and little tunny were among the top ten species in each area. Dolphin and great barracuda were among the top ten in all but one area. In the Gulf of Mexico, Spanish mackerel, king mackerel, and little tunny were among the top ten species in each area, with blue runner in seven of eight areas, and crevalle jack and Atlantic bonito in six of eight areas.

Table 4.—Ten most abundant species caught by trolling in each area off the U.S. south Atlantic coast and in the U.S. Caribbean during 1983 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Dolphin	7,669	1.71	37.08
2 Yellowfin tuna	4,086	0.91	19.75
3 King mackerel	3,361	0.75	16.25
4 Bluefish	2,949	0.66	14.26
5 Little tunny	743	0.17	3.59
6 Spanish mackerel	430	0.10	2.08
7 Wahoo	281	0.06	1.36
8 Albacore	230	0.05	1.11
9 White marlin	207	0.05	1.00
10 Blackfin tuna	188	0.04	0.91
	20,144		97.39
South Carolina			
1 Bluefish	909	1.08	35.83
2 King mackerel	520	0.62	20.50
3 Spanish mackerel	409	0.48	16.12
4 Crevalle jack	211	0.25	8.32
5 Great barracuda	93	0.11	3.67
6 Red drum	72	0.09	2.84
7 Dolphin	68	0.08	2.68
8 Yellowfin tuna	59	0.07	2.33
9 Greater amberjack	51	0.06	2.01
10 Little tunny	45	0.05	1.77
	2,437		96.07
Georgia			
1 King mackerel	102	0.57	21.17
2 Little tunny	89	0.49	18.46
3 Great barracuda	86	0.48	17.84
4 Bluefish	60	0.33	12.45
5 Spanish mackerel	37	0.21	7.68
6 Vermilion snapper	35	0.19	7.26
7 Dolphin	24	0.13	4.98
8 Greater amberjack	18	0.10	3.73
9 Black sea bass	15	0.08	3.11
Georgia (cont.)			
10.5 Cobia	8	0.00	1.66
10.5 Wahoo	8	0.00	1.66
	482		100.00
Northeast Florida			
1 Little tunny	480	0.89	37.94
2 King mackerel	238	0.44	18.81
3 Bluefish	144	0.27	11.38
4 Spanish mackerel	125	0.23	9.88
5 Great barracuda	101	0.19	7.98
6 Crevalle jack	67	0.13	5.30
7 Greater amberjack	40	0.07	3.16
8 Yellow jack	26	0.05	2.06
9 Atlantic bonito	11	0.02	0.87
10 Cutlassfish	10	0.02	0.79
	1,242		98.17
East Florida			
1 King mackerel	4,383	1.43	34.50
2 Little tunny	2,464	0.80	19.40
3 Atlantic bonito	1,714	0.56	13.49
4 Great barracuda	1,417	0.46	11.15
5 Dolphin	1,012	0.33	7.97
6 Spanish mackerel	694	0.23	5.46
7 Blue runner	293	0.10	2.31
8 Bluefish	142	0.05	1.12
9.5 Greater amberjack	80	0.03	0.63
9.5 Lesser amberjack	80	0.03	0.63
	12,279		96.66
Southeast Florida			
1 Dolphin	3,555	0.95	38.54
2 Atlantic bonito	1,232	0.33	13.36
3 King mackerel	1,125	0.30	12.20
Southeast Florida (cont.)			
4 Little tunny	737	0.20	7.99
5 Great barracuda	723	0.19	7.84
6 Spanish mackerel	448	0.12	4.86
7 Blackfin tuna	222	0.06	2.41
8 Blue runner	204	0.05	2.21
9 Wahoo	158	0.04	1.71
10 Hammerhead shark	145	0.04	1.57
	8,549		92.67
South Florida			
1 Dolphin	9,229	1.55	59.62
2 Great barracuda	1,652	0.28	10.67
3 Blackfin tuna	1,291	0.22	8.34
4 Little tunny	779	0.13	5.29
5 King mackerel	580	0.10	3.75
6 Atlantic bonito	310	0.05	2.00
7 Yellowtail snapper	235	0.04	1.52
8 Wahoo	221	0.04	1.43
9 Cero	212	0.04	1.36
10 Skipjack tuna	211	0.04	1.36
	14,720		95.34
U.S. Caribbean			
1 Dolphin	130	0.07	21.89
2 Great barracuda	104	0.06	17.51
3 Blue marlin	77	0.04	12.96
4 Little tunny	57	0.03	9.60
5 King mackerel	54	0.03	9.09
6 Yellowfin tuna	27	0.02	4.55
7 Wahoo	24	0.01	4.04
8 Skipjack tuna	23	0.01	3.87
9 Cero	22	0.01	3.70
10 Lizardfish	19	0.01	3.20
	537		90.41

Table 5.—Ten most abundant species caught by trolling in each area of the Gulf of Mexico during 1983 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Spanish mackerel	104	1.20	38.95
2 Crevalle jack	63	0.73	23.60
3 Ladyfish	34	0.40	12.73
4 Blue runner	28	0.33	10.49
5 Bluefish	20	0.23	7.49
6.5 Red drum	8	0.09	3.00
6.5 Little tunny	8	0.09	3.00
8.5 King mackerel	1	0.01	0.37
8.5 Atlantic bonito	1	0.01	0.37
	267		100.00
West Florida			
1 Spanish mackerel	1,610	1.47	45.73
2 Little tunny	614	0.56	17.44
3 Blue runner	436	0.40	12.38
4 King mackerel	395	0.36	11.22
5 Great barracuda	152	0.14	4.32
6 Crevalle jack	104	0.10	2.95
7 Gag	40	0.04	1.14
8 Greater amberjack	38	0.04	1.08
9 Ladyfish	30	0.03	0.85
10 Atlantic bonito	26	0.02	0.74
	3,445		97.85
Northwest Florida			
1 Blue runner	7,109	2.00	33.63
2 King mackerel	4,934	1.37	23.34
3 Atlantic bonito	2,893	0.80	13.69
4 Little tunny	2,247	0.62	10.63
5 Spanish mackerel	1,434	0.40	6.78
6 Ladyfish	587	0.16	2.78
7 Dolphin	583	0.16	2.76
8 Bluefish	479	0.13	2.27
9 Greater amberjack	266	0.07	1.26
Northwest Florida (cont.)			
10 Gray triggerfish	164	0.05	0.78
	20,696		97.92
Alabama			
1 Spanish mackerel	1,994	1.56	38.10
2 Little tunny	1,215	1.00	23.22
3 Blue runner	645	0.50	12.33
4 King mackerel	601	0.47	11.48
5 Atlantic bonito	368	0.29	7.03
6 Greater amberjack	119	0.09	2.27
7 Bluefish	93	0.07	1.78
8 Ladyfish	60	0.05	1.15
9 Cobia	41	0.03	0.78
10 Red snapper	31	0.02	0.59
	5,167		98.73
Mississippi			
1 Spanish mackerel	5,501	7.35	76.07
2 Blue runner	389	0.52	5.38
3 Red drum	317	0.42	4.38
4 Little tunny	304	0.41	4.20
5 Crevalle jack	203	0.27	2.81
6 Ladyfish	196	0.26	2.71
7 King mackerel	123	0.16	1.70
8 Red snapper	65	0.09	0.90
9 Cobia	47	0.06	0.65
10 Blacktip shark	31	0.04	0.43
	7,176		99.23
Louisiana			
1 Spanish mackerel	1,649	2.54	42.52
2 Dolphin	741	1.14	19.11
3 King mackerel	647	1.00	16.68
Louisiana (cont.)			
4 Little tunny	238	0.37	6.14
5 Blue runner	146	0.23	3.77
6 Yellowfin tuna	93	0.14	2.40
7 Red drum	88	0.14	2.27
8 Bluefish	85	0.13	2.19
9 Crevalle jack	42	0.07	1.08
10 Blackfin tuna	34	0.05	0.88
	3,763		97.04
North Texas			
1 King Mackerel	1,093	2.18	35.88
2 Dolphin	688	1.37	22.59
3 Little tunny	487	0.97	15.99
4 Spanish mackerel	203	0.40	6.66
5 Greater amberjack	157	0.31	5.15
6 Atlantic bonito	80	0.16	2.63
7 Unidentified sharks	78	0.16	2.56
8 Cobia	61	0.12	2.00
9 Crevalle jack	54	0.11	1.77
10 Blue runner	50	0.10	1.64
	2,951		96.87
South Texas			
1 King mackerel	1,576	0.61	36.01
2 Little tunny	626	0.24	14.30
3 Crevalle jack	512	0.20	11.70
4 Dolphin	317	0.12	7.24
5 Blackfin tuna	238	0.10	5.44
6 Atlantic bonito	237	0.10	5.42
7 Spanish mackerel	189	0.07	4.32
8 Yellowfin tuna	141	0.05	3.22
9 Wahoo	73	0.03	1.67
10 Cobia	10	0.03	0.23
	3,919		89.55

Table 6.—Ten most abundant species caught by other then trolling in each area off the U.S. south Atlantic coast during 1983 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
North Carolina			
1 Black sea bass	12,067	32.18	73.49
2 Unidentified porgies	2,470	6.59	15.04
3 Unidentified grunts	1,234	3.29	7.52
4 Red snapper	432	1.15	2.63
5 Unidentified snappers	70	0.19	0.43
6 Gag	61	0.16	0.37
7 Wrasses	21	0.06	0.13
8 King mackerel	14	0.04	0.09
9 Vermilion snapper	11	0.03	0.07
10 Toadfish	8	0.02	0.05
	16,388		99.82
South Carolina			
1 Black sea bass	20,620	50.79	90.74
2 Unidentified porgies	783	1.93	3.45
3 Vermilion snapper	651	1.60	1.99
4 Red snapper	251	0.62	1.11
5 Bluefish	137	0.34	0.60
6 Scamp	114	0.28	0.50
7 Gray triggerfish	107	0.26	0.47
8 Gag	43	0.11	0.19
9 Unidentified sharks	10	0.03	0.04
10 Greater amberjack	3	0.01	0.01
	22,719		99.10
Georgia			
1 Vermilion snapper	534	4.56	45.68
2 Bluefish	213	1.82	18.22
3 Red snapper	187	1.60	16.00
4 Black sea bass	83	0.71	7.10
Georgia (cont.)			
5 King mackerel	58	0.50	4.96
6 Dolphin	30	0.26	2.57
7 Greater amberjack	28	0.24	2.40
8 Red drum	8	0.07	0.68
9.5 Cobia	7	0.06	0.60
9.5 Great barracuda	7	0.06	0.60
	1,155		98.81
Northeast Florida			
1 Black sea bass	1,147	3.79	56.73
2 Whiting	163	0.54	8.06
3 Unidentified seatrout	152	0.50	7.52
4 Bluefish	139	0.46	6.87
5 Hardhead catfish	88	0.29	4.35
6 Red drum	57	0.19	2.82
7.5 Pinfish	45	0.15	2.23
7.5 Unidentified sharks	45	0.15	2.23
9 Unidentified porgies	34	0.11	1.68
10 Sheepshead	27	0.09	1.34
	1,897		93.83
East Florida			
1 Black sea bass	2,083	4.42	41.44
2 Vermilion snapper	457	0.97	9.09
3 Unidentified grunts	444	0.94	8.83
4 Gray triggerfish	298	0.63	5.93
5 Red snapper	294	0.62	5.85
6 Yellowtail snapper	287	0.61	5.71
7 Greater amberjack	265	0.56	5.27
East Florida (cont.)			
8 Blue runner	142	0.30	2.83
9 Snowy grouper	80	0.17	1.59
10 Bluefish	70	0.15	1.39
	4,420		87.93
Southeast Florida			
1 Greater amberjack	392	1.01	23.31
2 Unidentified snappers	197	0.51	11.71
3 Snowy grouper	178	0.46	10.58
4 Blue runner	158	0.41	9.39
5 Unidentified tilefish	145	0.37	8.62
6 Vermilion snapper	78	0.20	4.64
7 Dolphin	62	0.16	3.69
8 Spanish mackerel	60	0.15	3.57
9 Lane snapper	43	0.11	2.56
10 Yellowtail snapper	42	0.11	2.50
	1,355		80.57
South Florida			
1 Yellowtail snapper	1,176	0.96	22.53
2 King mackerel	612	0.50	11.72
3 Unidentified grunts	459	0.38	8.79
4 Greater amberjack	314	0.26	6.02
5 Gray snapper	283	0.23	5.42
6 Mutton snapper	262	0.22	5.02
7 Blue runner	252	0.21	4.83
8 Great barracuda	203	0.17	3.89
9 Ladyfish	157	0.13	3.01
10 Crevalle jack	146	0.12	2.80
	3,864		74.01

Shown in Tables 6 and 7 are the top ten species caught by methods other than trolling. Along the U.S. south Atlantic, black sea bass, vermilion snapper, and greater amberjack were caught in five of eight areas, while red snapper was reported in four of eight areas. In the Gulf of Mexico, seatrouts (both spotted and unidentified) and gray triggerfish were among the top ten species in five of eight areas with red drum and gag in four of eight areas.

Monthly CPH's for species in each of the 16 surveyed areas were computed. In this paper, only the results for each area's five most abundantly caught species in the U.S. south Atlantic and the Caribbean (Tables 8 and 9) and in the Gulf of Mexico (Tables 10 and 11) were compared. For example, in the U.S. south Atlantic, king mackerel were most abundant (CPH >2) during October and November off North Carolina, December off northeast Florida, and August and November off east Florida (Table 8). The Gulf of Mexico provided good catches of king mackerel (CPH >2) in December off west Florida, August and September off northwest Florida, January, February, and September off Louisiana, and in June, July, and August off north Texas (Table 10). Generally, king mackerel monthly CPH was highest in the Gulf of Mexico during summer months, while off the U.S. south Atlantic and in the U.S. Caribbean, CPH's were greatest in the fall. Another example shows Spanish mackerel caught along the U.S. south Atlantic (CPHs <2) but appearing to be more abundant (CPH >3) in Gulf waters, especially off Mississippi (Tables 8 and 10). A final example shows dolphin, the most abundant troll-caught species in 1983, caught most often in late spring and early summer in all surveyed areas with over 89 percent of this species caught in U.S. south Atlantic and Caribbean waters (Tables 8 and 10).

Monthly CPH data for fishes caught by methods other than trolling show a more defined relative abundance by area. Black sea bass was taken intermittently throughout the fishing season (Table 9) but was abundant only in spring along the U.S. south Atlantic areas (North Carolina through east Florida). In the Gulf of Mexico, however, black sea bass was not abundant, but red snapper was abundant from late summer through early fall, especially in the northern Gulf (Table 11). In the Caribbean area, trolling was the only recorded fishing method.

The mackerels and tunas (Scombridae) made up 54.8 percent of the troll catch, pointing out the dominance of these coastal pelagic species to the southeastern United States. For fishing methods other than trolling, snappers (Lutjanidae) with 29.3 percent, sea basses (Serranidae) with 19.3 percent, and drums (Sciaenidae) with 26.6 percent of the total catch emphasized the importance of those demersal species.

Table 7.—Ten most abundant species caught by other than trolling in each area in the Gulf of Mexico during 1983 charterboat survey.

Area, rank, and species	Number caught	CPH	Percent of total catch w/i area
Southwest Florida			
1 Unidentified seatrout	4,961	1.29	22.30
2 Red grouper	3,358	0.87	15.11
3 Gray snapper	1,507	0.39	6.78
4 Unidentified grunts	1,406	0.36	6.32
5 Ladyfish	1,398	0.36	6.29
6 Red drum	1,312	0.34	5.90
7 Gag	1,213	0.31	5.45
8 Spotted seatrout	1,081	0.28	4.86
9 Crevalle jack	1,070	0.28	4.81
10 Hardhead catfish	660	0.17	2.97
	17,966		81.79
West Florida			
1 Spotted seatrout	936	0.66	14.64
2 Gag	502	0.35	7.85
3 Ladyfish	469	0.33	7.34
4 Black sea bass	464	0.33	7.26
5 Spanish mackerel	420	0.30	6.57
6 Unidentified seatrout	389	0.28	6.08
7 Crevalle jack	387	0.27	6.05
8 Unidentified grunts	337	0.24	5.27
9 Red drum	293	0.21	4.58
10 Red grouper	257	0.18	4.02
	4,454		69.66
Northwest Florida			
1 Red snapper	13,340	3.87	26.03
2 Vermilion snapper	11,461	3.32	22.37
3 Unidentified porgies	9,694	2.81	18.92
4 Gray triggerfish	8,504	2.47	16.60
5 Greater amberjack	4,485	1.30	8.75
6 Gag	1,179	0.34	2.30
7 Little tunny	506	0.15	0.99
8 Scamp	452	0.13	0.88
9 Dolphin	402	0.12	0.78
Northwest Florida (cont.)			
10 Blue runner	267	0.08	0.52
	50,290		98.14
Alabama			
1 Red snapper	7,070	8.84	68.65
2 Gray triggerfish	1,771	2.21	17.20
3 Greater amberjack	637	0.80	6.19
4 Unidentified grunts	213	0.27	2.07
5 Vermilion snapper	165	0.21	1.60
6 Spadefish	111	0.14	1.08
7 Silver perch	91	0.11	0.88
8 Black sea bass	45	0.06	0.44
9 Gag	33	0.04	0.32
10 Gray snapper	30	0.04	0.29
	10,166		98.72
Mississippi			
1 Whiting	472	5.00	41.96
2 Spotted seatrout	286	3.03	25.42
3 Red snapper	163	1.73	14.49
4 Sand seatrout	70	0.74	6.22
5 Unidentified sharks	50	0.53	4.44
6 Ladyfish	30	0.32	2.67
7 Little tunny	17	0.18	1.51
8 Blue runner	10	0.11	0.89
9 Blacktip shark	8	0.09	0.64
10 Cobia	7	0.07	0.62
	1,113		98.86
Louisiana			
1 Atlantic croaker	23,261	12.29	28.11
2 Red snapper	23,199	12.07	28.04
3 Sand seatrout	17,785	9.25	21.49
4 Unidentified seatrout	8,407	4.37	10.16
Louisiana (cont.)			
5 Gray triggerfish	1,835	0.95	2.22
6 Greater amberjack	1,595	0.83	1.93
7 Dolphin	1,313	0.68	1.59
8 Bluefish	934	0.49	1.13
9 King mackerel	907	0.47	1.10
10 Pinfish	780	0.41	0.94
	80,016		96.71
North Texas			
1 Red snapper	4,867	8.00	70.17
2 Bluefish	401	0.66	5.78
3 Gray triggerfish	209	0.34	3.01
4 King mackerel	195	0.32	2.81
5 Little tunny	194	0.32	2.80
6 Unidentified seatrout	191	0.31	2.75
7 Spotted seatrout	160	0.26	2.31
8 Unidentified sharks	144	0.24	2.08
9 Cobia	140	0.23	2.02
10 Red drum	66	0.11	0.95
	6,567		94.68
South Texas			
1 Red snapper	621	1.77	30.16
2 Spotted seatrout	383	1.09	18.60
3 Sand seatrout	223	0.64	10.83
4 Unidentified seatrout	222	0.63	10.78
5 Red drum	156	0.44	7.58
6 Atlantic croaker	87	0.25	4.23
7 Gray triggerfish	70	0.20	3.40
8 Greater amberjack	64	0.18	3.11
9 Bluefish	30	0.10	1.46
10.5 Sheepshead	20	0.06	0.97
10.5 Black drum	20	0.06	0.97
	1,896		91.19

Table 8.—Mean catch per boat hour by month for five most abundant species caught by trolling off each U.S. south Atlantic and Caribbean area during 1983 charterboat survey.

Area and species	Mean catch per boat hour											
	January	February	March	April	May	June	July	August	September	October	November	December
North Carolina												
Dolphin	—	—	—	0.00	0.95	3.31	3.29	1.42	0.88	0.43	0.00	0.00
Yellowfin tuna	—	—	—	0.00	0.99	1.83	1.37	0.78	0.28	0.39	0.00	0.00
King mackerel	—	—	—	0.03	1.16	0.32	0.11	0.06	0.32	2.83	2.94	1.75
Bluefish	—	—	—	12.01	2.37	0.07	0.00	0.02	0.00	0.27	2.20	4.13
Little tunny	—	—	—	0.19	0.23	0.11	0.08	0.05	0.14	0.39	0.61	0.38
South Carolina												
Bluefish	—	—	—	2.53	1.62	1.17	1.47	1.07	0.06	0.52	0.84	—
King mackerel	—	—	—	0.63	0.89	0.29	0.23	0.28	1.02	1.33	0.89	—
Spanish mackerel	—	—	—	0.00	0.13	1.28	0.37	0.60	0.64	0.07	0.00	—
Crevalle jack	—	—	—	0.00	0.00	0.42	0.27	0.59	0.00	0.10	0.00	—
Great barracuda	—	—	—	0.00	0.00	0.07	0.20	0.18	0.18	0.02	0.00	—
Georgia												
King mackerel	—	—	—	—	0.40	0.47	0.96	0.45	0.80	—	—	—
Little tunny	—	—	—	—	0.24	0.16	0.21	0.86	0.67	—	—	—
Great barracuda	—	—	—	—	0.00	0.36	0.35	0.81	0.00	—	—	—
Bluefish	—	—	—	—	1.28	0.63	0.13	0.00	0.00	—	—	—
Spanish mackerel	—	—	—	—	0.00	0.00	0.00	0.50	0.00	—	—	—
Northeast Florida												
Little tunny	—	—	—	1.93	1.39	0.40	0.55	0.86	0.81	0.58	0.33	1.14
King mackerel	—	—	—	0.09	0.66	0.66	0.46	0.31	0.22	0.23	0.00	2.14
Bluefish	—	—	—	0.53	0.43	0.01	0.05	0.04	0.47	0.07	2.15	0.00
Spanish mackerel	—	—	—	0.46	0.41	0.09	0.09	0.20	0.38	0.18	0.00	0.00
Great barracuda	—	—	—	0.00	0.04	0.14	0.34	0.42	0.34	0.07	0.00	0.00

Continued on next page.

Table 8.—Continued.

Area and species	Mean catch per boat hour											
	January	February	March	April	May	June	July	August	September	October	November	December
East Florida												
King mackerel	—	—	0.42	1.12	1.12	1.22	0.88	2.16	1.42	1.06	3.22	1.05
Little tunny	—	—	0.00	0.36	0.80	0.57	0.93	1.91	0.75	0.44	0.58	0.12
Atlantic bonito	—	—	0.21	0.49	0.32	0.25	0.67	1.07	0.99	0.13	0.45	0.27
Great barracuda	—	—	0.64	0.19	0.11	0.21	0.41	0.55	0.63	0.21	0.17	2.14
Dolphin	—	—	0.10	0.32	0.28	0.78	0.38	0.17	0.23	0.38	0.15	0.40
Southeast Florida												
Dolphin	—	—	0.13	0.76	0.98	2.25	0.56	0.39	1.79	0.80	0.28	0.60
Atlantic bonito	—	—	0.00	0.02	0.09	0.06	0.35	1.47	0.42	0.17	0.31	0.47
King mackerel	—	—	0.00	0.12	0.17	0.09	0.14	0.46	0.31	0.58	0.64	0.38
Little tunny	—	—	0.00	0.09	0.02	0.04	0.20	0.77	0.30	0.19	0.19	0.13
Great barracuda	—	—	0.00	0.03	0.05	0.14	0.30	0.42	0.17	0.30	0.23	0.30
South Florida												
Dolphin	0.08	0.29	0.00	1.46	2.83	3.19	1.06	1.15	1.46	0.83	0.17	0.27
Great barracuda	0.46	0.35	0.71	0.27	0.09	0.08	0.20	0.51	0.51	0.44	0.37	0.34
Blackfin tuna	0.08	0.00	0.00	0.39	0.25	0.27	0.12	0.17	0.19	0.25	0.12	0.20
Little tunny	0.23	0.29	0.06	0.14	0.15	0.07	0.28	0.16	0.19	0.02	0.07	0.05
King mackerel	0.56	1.86	0.00	0.02	0.00	0.00	0.01	0.03	0.00	0.12	0.30	0.50
U.S. Caribbean Sea												
Dolphin	—	—	0.84	0.16	0.12	0.07	0.01	0.00	0.04	0.00	0.09	0.06
Great barracuda	—	—	0.00	0.08	0.07	0.03	0.04	0.05	0.10	0.11	0.05	0.16
Blue marlin	—	—	0.02	0.00	0.00	0.07	0.11	0.06	0.03	0.01	0.01	0.00
Little tunny	—	—	0.00	0.00	0.03	0.02	0.00	0.00	0.01	0.02	0.07	0.46
King mackerel	—	—	0.00	0.04	0.02	0.02	0.02	0.01	0.05	0.06	0.08	0.07

Table 9.—Mean catch per boat hour by month for five most abundant species caught by other than trolling off each U.S. south Atlantic area during 1983 charterboat survey.

Area and species	Mean catch per boat hour									
	March	April	May	June	July	August	September	October	November	December
North Carolina										
Black sea bass	—	38.47	46.40	25.70	34.60	28.21	31.12	0.00	28.00	—
Porgies	—	5.75	10.28	5.02	8.90	5.32	5.45	3.00	4.52	—
Grunts	—	0.51	0.60	4.07	6.33	3.85	5.12	0.00	0.00	—
Red snapper	—	0.00	0.00	0.00	0.00	6.29	0.00	7.00	0.00	—
Snappers	—	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	—
South Carolina										
Black sea bass	—	9.85	56.30	80.73	49.07	65.46	41.51	—	—	—
Porgies	—	1.12	2.59	0.00	0.00	0.36	4.25	—	—	—
Vermilion snapper	—	0.00	0.00	0.00	0.14	1.38	4.48	—	—	—
Red snapper	—	0.00	0.43	1.00	1.14	0.72	0.57	—	—	—
Bluefish	—	0.95	1.32	0.00	0.00	0.00	0.00	—	—	—
Georgia										
Vermilion snapper	—	9.33	0.51	5.56	4.24	0.00	0.00	—	—	—
Bluefish	—	0.00	2.64	4.89	0.00	0.00	0.00	—	—	—
Red snapper	—	4.67	1.15	0.09	0.00	0.00	0.00	—	—	—
Black sea bass	—	0.00	1.41	0.76	0.48	0.33	0.00	—	—	—
King mackerel	—	0.33	0.08	0.22	1.57	2.33	0.00	—	—	—
Northeast Florida										
Black sea bass	—	3.99	21.48	5.28	6.25	0.34	0.00	4.05	0.14	—
Kingfish	—	1.07	0.00	0.30	1.00	0.28	0.96	0.65	0.11	—
Seatrout	—	0.01	0.00	0.00	0.00	0.00	0.67	1.35	1.57	—
Bluefish	—	0.28	0.00	0.02	0.00	0.00	0.00	0.00	1.60	—
Hardhead catfish	—	0.74	0.00	0.40	0.25	0.00	0.00	0.09	0.00	—
East Florida										
Black sea bass	4.63	7.95	5.42	2.32	3.42	3.84	4.29	4.25	0.28	0.00
Vermilion snapper	0.00	0.91	0.82	0.36	1.01	0.26	2.20	2.44	1.03	0.00
Grunts	0.00	0.51	1.24	0.19	1.01	1.18	0.00	6.07	0.00	0.00
Gray triggerfish	0.50	0.68	0.27	0.77	0.35	0.42	0.86	2.04	0.00	0.00
Red snapper	0.00	0.34	0.44	0.62	0.21	0.68	1.66	1.31	0.21	0.67
Southeast Florida										
Greater amberjack	—	0.85	2.83	0.51	0.04	0.00	0.00	0.14	0.46	0.67
Snappers	—	0.11	0.00	0.00	0.00	0.00	0.00	2.95	2.71	1.33

Continued on next page

Table 9.—Continued.

Area and species	Mean catch per boat hour									
	March	April	May	June	July	August	September	October	November	December
Southeast Florida (cont.)										
Snowy grouper	—	0.05	0.11	0.82	1.13	1.01	1.39	1.22	0.00	0.30
Blue runner	—	0.03	1.20	0.00	0.08	0.00	0.00	0.03	1.54	0.00
Tilefish	—	0.19	0.46	0.51	0.49	0.78	1.13	0.00	0.04	0.42
South Florida										
Yellowtail snapper	0.70	1.06	0.25	0.00	4.44	1.72	1.59	1.14	0.63	0.44
King mackerel	0.05	0.07	0.04	0.00	0.00	0.15	0.09	0.29	0.58	2.46
Grunts	0.00	0.75	0.34	0.00	0.84	0.04	0.28	0.10	0.13	0.26
Greater amberjack	0.55	0.41	0.25	0.36	0.30	0.43	0.09	0.05	0.09	0.19
Gray snapper	0.00	0.13	0.11	0.02	0.30	0.24	0.21	0.40	0.66	0.16

Table 10.—Mean catch per boat hour by month for five most abundant species caught by trolling off each Gulf of Mexico area during 1983 charterboat survey.

Area and species	Mean catch per boat hour											
	January	February	March	April	May	June	July	August	September	October	November	December
Southwest Florida												
Spanish mackerel	—	—	—	0.56	—	—	—	1.33	0.00	1.47	1.00	—
Crevalle jack	—	—	—	0.00	—	—	—	0.00	0.00	0.98	1.00	—
Ladyfish	—	—	—	0.00	—	—	—	0.00	0.00	0.56	0.00	—
Blue runner	—	—	—	0.00	—	—	—	0.00	0.00	0.46	0.00	—
Bluefish	—	—	—	1.00	—	—	—	0.00	0.00	0.00	0.00	—
West Florida												
Spanish mackerel	—	—	—	0.64	1.14	1.56	1.73	1.47	1.77	2.33	2.35	0.03
Little tunny	—	—	—	0.28	0.26	0.55	0.29	0.66	0.92	0.64	0.36	3.39
Blue runner	—	—	—	0.28	1.20	0.51	0.11	0.08	0.55	0.28	0.03	0.00
King mackerel	—	—	—	0.51	0.25	0.22	0.18	0.12	0.10	0.20	0.53	3.13
Great barracuda	—	—	—	0.23	0.07	0.34	0.19	0.21	0.27	0.02	0.00	0.00
Northwest Florida												
Blue runner	—	—	0.00	0.00	7.68	6.39	0.01	0.05	0.02	0.01	0.00	—
King mackerel	—	—	0.00	0.00	0.01	0.35	1.82	2.47	2.34	0.68	0.03	—
Atlantic bonito	—	—	0.00	0.00	2.84	2.74	0.17	0.06	0.04	0.19	0.53	—
Little tunny	—	—	0.00	0.00	0.35	1.29	0.95	0.44	0.36	0.53	0.09	—
Spanish mackerel	—	—	0.00	1.07	1.70	0.38	0.18	0.07	0.06	0.12	0.56	—
Alabama												
Spanish mackerel	—	—	—	1.73	0.98	1.41	1.21	2.13	3.50	0.22	0.27	—
Little tunny	—	—	—	0.00	0.88	0.76	0.65	1.22	1.36	1.46	1.09	—
Blue runner	—	—	—	0.00	0.42	1.34	0.43	0.38	0.32	0.01	0.00	—
King mackerel	—	—	—	0.00	0.08	0.15	0.86	0.69	0.75	0.14	0.00	—
Atlantic bonito	—	—	—	0.02	0.58	0.65	0.38	0.02	0.00	0.05	0.18	—
Mississippi												
Spanish mackerel	—	—	—	11.33	9.86	11.84	10.57	2.86	2.01	0.08	—	—
Blue runner	—	—	—	0.00	0.36	0.65	0.81	0.63	0.15	0.00	—	—
Red drum	—	—	—	0.00	0.26	0.23	0.19	0.76	0.71	0.73	—	—
Little tunny	—	—	—	0.00	0.14	0.57	0.63	0.51	0.15	0.23	—	—
Crevalle jack	—	—	—	0.24	0.06	0.29	0.25	0.39	0.29	0.58	—	—
Louisiana												
Spanish mackerel	0.00	0.00	—	—	1.31	0.01	1.68	3.34	6.45	3.99	0.26	—
Dolphin	0.00	0.00	—	—	8.13	1.23	1.99	1.94	0.00	0.00	0.00	—
King mackerel	2.03	2.49	—	—	0.00	0.00	0.00	0.82	2.10	1.34	1.16	—
Little tunny	0.08	0.19	—	—	0.31	0.00	0.13	0.52	0.58	0.86	0.52	—
Blue runner	0.00	0.00	—	—	0.00	0.05	0.11	0.29	0.23	0.66	0.10	—
North Texas												
King mackerel	—	—	—	0.50	1.43	2.27	2.90	2.43	0.91	0.14	0.00	—
Dolphin	—	—	—	0.00	2.92	0.82	0.08	3.17	0.07	0.00	0.00	—
Little tunny	—	—	—	0.00	0.10	0.61	1.84	1.18	0.40	0.36	0.00	—
Spanish mackerel	—	—	—	0.00	0.10	0.08	0.15	0.85	0.73	0.50	1.00	—
Greater amberjack	—	—	—	0.00	0.51	0.60	0.45	0.00	0.00	0.43	0.00	—
South Texas												
King mackerel	—	—	—	0.15	0.25	0.53	0.71	0.92	0.71	0.40	0.29	0.20
Little tunny	—	—	—	0.87	0.37	0.14	0.13	0.16	0.46	0.30	0.36	1.20
Crevalle jack	—	—	—	0.23	0.51	0.31	0.13	0.08	0.06	0.02	0.23	0.00
Dolphin	—	—	—	0.02	0.05	0.11	0.17	0.15	0.14	0.14	0.01	0.00
Blackfin tuna	—	—	—	0.01	0.05	0.02	0.06	0.07	0.34	0.02	0.07	0.00

Table 11.—Mean catch per boat hour by month for five most abundant species caught by other than trolling off each Gulf of Mexico area during 1983 charterboat survey.

Area and species	Mean catch per boat hour											
	January	February	March	April	May	June	July	August	September	October	November	December
Southwest Florida												
Seatrout	—	—	—	3.18	0.96	1.33	1.58	1.33	0.55	0.82	0.86	0.39
Red grouper	—	—	—	0.15	0.14	0.45	0.87	1.84	1.26	2.13	1.26	0.69
Gray snapper	—	—	—	0.11	0.06	0.09	0.10	0.39	0.69	0.87	1.14	0.73
Grunts	—	—	—	0.42	0.20	0.13	0.39	0.39	0.39	0.54	0.55	0.57
Ladyfish	—	—	—	0.79	0.26	0.20	0.24	0.27	0.15	0.16	0.66	0.69
West Florida												
Spotted seatrout	—	—	0.00	0.51	0.10	0.28	0.31	1.52	0.86	1.22	0.42	0.90
Gag	—	—	2.27	0.16	0.58	0.37	0.14	0.41	0.38	0.15	0.40	0.31
Ladyfish	—	—	0.00	0.51	0.39	0.24	0.22	0.26	0.30	0.68	0.27	0.27
Black sea bass	—	—	0.91	0.18	0.17	0.05	0.03	0.01	0.13	0.12	1.53	1.09
Spanish mackerel	—	—	0.00	0.01	0.15	0.01	0.04	0.01	0.08	0.78	1.94	0.00
Northwest Florida												
Red snapper	—	—	3.60	3.12	2.38	3.19	3.54	4.64	5.14	5.15	7.08	—
Vermilion snapper	—	—	2.80	1.60	1.86	2.52	2.88	4.92	6.59	3.42	4.95	—
Porgies	—	—	4.80	3.95	3.27	2.16	2.47	3.45	3.00	2.26	0.68	—
Gray triggerfish	—	—	0.00	1.64	1.71	1.96	2.20	2.35	3.50	3.99	3.88	—
Greater amberjack	—	—	0.80	0.68	1.45	2.23	1.25	1.05	1.44	0.70	0.90	—
Alabama												
Red snapper	—	—	—	6.19	4.68	6.70	8.45	9.11	12.94	13.54	9.05	—
Gray triggerfish	—	—	—	2.31	3.43	1.82	1.90	1.55	1.94	3.06	1.70	—
Greater amberjack	—	—	—	0.14	1.23	1.89	0.76	0.57	0.36	0.51	0.48	—
Grunts	—	—	—	0.66	0.15	0.25	0.08	0.17	0.31	0.10	1.00	—
Vermilion snapper	—	—	—	0.00	0.08	0.22	0.09	0.26	0.41	0.27	0.43	—
Mississippi												
Kingfish	—	—	—	0.00	14.75	0.00	0.00	0.00	—	0.00	—	—
Spotted seatrout	—	—	—	0.00	0.00	4.41	4.14	2.86	—	8.20	—	—
Red snapper	—	—	—	9.67	1.88	0.00	0.71	3.33	—	0.00	—	—
Sand seatrout	—	—	—	0.00	1.19	0.00	1.43	0.00	—	0.80	—	—
Sharks	—	—	—	0.00	0.00	0.00	3.57	0.00	—	0.00	—	—
Louisiana												
Atlantic croaker	11.29	11.97	13.20	12.51	3.51	4.48	6.12	11.42	13.33	23.01	19.64	21.45
Red snapper	2.19	3.39	5.07	4.51	13.86	10.55	15.85	16.02	20.83	10.45	6.57	2.88
Sand seatrout	0.00	1.55	0.00	0.00	1.73	1.09	1.80	5.31	6.25	13.47	28.22	43.51
Seatrout	14.67	15.35	18.64	20.05	0.56	1.28	0.38	0.00	0.00	1.90	13.42	22.39
Gray triggerfish	0.14	0.65	0.82	0.33	3.13	1.24	0.57	0.63	0.84	1.28	0.64	0.54
North Texas												
Red snapper	—	—	—	7.67	5.46	6.71	4.30	8.74	9.66	13.57	14.24	16.62
Bluefish	—	—	—	0.03	0.00	0.66	0.05	1.71	1.71	0.98	0.62	0.69
Gray triggerfish	—	—	—	0.87	0.32	0.45	0.03	0.38	0.42	0.57	0.35	0.31
King mackerel	—	—	—	0.00	0.14	1.27	0.23	0.27	0.19	0.00	0.03	0.00
Little tunny	—	—	—	0.00	0.37	0.21	0.50	0.59	0.44	0.00	0.00	0.00
South Texas												
Red snapper	—	—	—	2.53	1.55	0.06	10.00	7.63	1.26	3.17	0.26	0.00
Spotted seatrout	—	—	—	0.00	1.07	2.03	0.00	0.00	0.00	1.38	0.98	4.57
Sand seatrout	—	—	—	0.00	1.11	0.20	0.00	0.00	0.00	0.64	1.15	5.71
Seatrout	—	—	—	0.89	0.00	0.00	0.00	0.00	0.58	0.00	2.07	0.00
Red drum	—	—	—	0.26	0.48	0.28	0.00	0.00	0.23	0.74	0.21	1.57

Discussion

Caution must be exercised in generalizing from the 1983 data for several reasons: 1) Effort distribution by fishing zone and fishing method may not be representative of the overall fishery for any particular area; 2) our classification of methods other than trolling includes bottom fishing, drift fishing (where the bait is allowed to "drift" with the prevailing current), and fly-lining, where such methods can produce catches of pelagic species; 3) the CPH from any area within the surveyed area could reflect seasonal target species preferred by charterboat clients rather than actual species abundance; 4) although obvious species identification errors were corrected, the geographical scope of the survey area undoubtedly caused some confusion as to the common names of certain species. For example, "albacore" in North Carolina could be either little tunny, *Euthynnus alletteratus*; skipjack tuna, *E. pelamis*; or the true albacore, *Thunnus alalunga*. Thus, there may be some species misidentifications in other areas. These and other problems are being rectified for future surveys as project personnel and captains become more familiar with survey objectives and methods.

Our success in 1983 indicates that charterboat CPH is obtainable and may be used in indicating the abundance of

Table 12.—Species composition of catches by trolling between areas surveyed during 1982 and 1983 charterboat surveys off the southeastern United States.

	1982		1983	
Area	Top ten species	CPH	Top ten species	CPH
North Carolina	Dolphin	3.83	Dolphin	1.71
	Bluefish	1.69	Yellowfin tuna	0.91
	Yellowfin tuna	0.79	King mackerel	0.75
	King mackerel	0.35	Bluefish	0.66
	Little tunny	0.19	Little tunny	0.17
	White marlin	0.05	Spanish mackerel[1]	0.10
	Wahoo	0.04	Wahoo	0.06
	Blackfin tuna	0.03	Albacore	0.05
	Atlantic bonito[1]	0.02	White marlin	0.05
	Albacore	0.01	Blackfin tuna	0.04
	Hours fished = 1,368.0		Hours fished = 4,498.5	
South Florida	Dolphin	1.70	Dolphin	1.55
	Great barracuda	0.59	Great barracuda	0.28
	Yellowtail snapper	0.13	Blackfin tuna[1]	0.22
	Cero	0.11	Little tunny	0.13
	King mackerel	0.11	King mackerel	0.10
	Little tunny	0.10	Atlantic bonito	0.05
	Atlantic bonito	0.07	Yellowtail snapper	0.04
	Wahoo	0.03	Wahoo	0.04
	Black grouper[1]	0.03	Cero	0.04
	Sailfish[1]	0.03	Skipjack tuna[1]	0.04
	Hours fished = 1,370.0		Hours fished = 5,938.5	
Northwest Florida	Blue runner	1.81	Blue runner	2.00
	Spanish mackerel	1.68	King mackerel	1.37
	Little tunny	1.12	Atlantic bonito	0.80
	King mackerel	0.72	Little tunny	0.62
	Bluefish	0.55	Spanish mackerel	0.40
	Dolphin	0.36	Ladyfish	0.16
	Atlantic bonito	0.20	Dolphin	0.16
	Ladyfish	0.11	Bluefish	0.13
	Greater amberjack	0.09	Greater amberjack	0.07
	Red drum[1]	0.03	Gray triggerfish[1]	0.05
	Hours fished = 576.5		Hours fished = 3,603.0	
Louisiana	Dolphin	9.19	Spanish mackerel	2.54
	Spanish mackerel	1.20	Dolphin	1.14
	Red drum	0.66	King mackerel	1.00
	Little tunny	0.65	Little tunny	0.37
	Blue runner	0.48	Blue runner	0.23
	Crevalle jack	0.25	Yellowfin tuna[1]	0.14
	Wahoo[1]	0.19	Red drum	0.14
	Bluefish	0.18	Bluefish	0.13
	King mackerel	0.11	Crevalle jack	0.07
	Cobia[1]	0.03	Blackfin tuna[1]	0.05
	Hours fished = 302.5		Hours fished = 650.0	
South Texas	King mackerel	1.28	King mackerel	0.61
	Spanish mackerel	0.52	Little tunny	0.24
	Dolphin	0.14	Crevalle jack	0.20
	Crevalle jack	0.11	Dolphin	0.12
	Cobia	0.07	Blackfin tuna[1]	0.09
	Atlantic sharpnose shark[1]	0.06	Atlantic bonito[1]	0.09
	Red snapper[1]	0.04	Spanish mackerel	0.07
	Blacktip shark[1]	0.04	Yellowfin tuna[1]	0.05
	Little tunny	0.03	Wahoo[1]	0.03
	Unidentified sharks[1]	0.01	Cobia	0.03
	Hours fished = 771.0		Hours fished = 2,590.5	

[1]Species change from 1982 to 1983.

Table 13.—Species composition of catches by other than trolling between areas in areas surveyed during 1982 and 1983 charterboat surveys of the southeastern United States.

	1982		1983	
Area	Top ten species	CPH	Top ten species	CPH
South Florida	Yellowtail snapper	2.64	Yellowtail snapper	0.98
	Greater amberjack	1.64	King mackerel[1]	0.50
	Lane snapper[1]	0.57	Grunts[1]	0.38
	Red grouper[1]	0.40	Greater amberjack	0.26
	Gray snapper	0.26	Gray snapper	0.23
	Great barracuda	0.09	Mutton snapper[1]	0.22
	Cobia[1]	0.02	Blue runner[1]	0.21
	Atlantic bonito[1]	0.02	Great barracuda	0.17
	Warsaw grouper[1]	0.02	Ladyfish[1]	0.13
	Jewfish[1]	0.02	Crevalle jack[1]	0.12
	Hours fished = 57.5		Hours fished = 1,219.5	
Louisiana	Atlantic croaker	6.20	Atlantic croaker	12.29
	Red snapper	3.69	Red snapper	12.07
	Sand seatrout	2.62	Sand seatrout	9.25
	Dolphin	2.54	Seatrout	4.37
	Seatrout	0.80	Gray triggerfish	0.98
	Blue runner[1]	0.65	Greater amberjack[1]	0.83
	Gray triggerfish	0.63	Dolphin	0.66
	King mackerel	0.52	Bluefish	0.49
	Bluefish	0.37	King mackerel	0.47
	Blacktip shark[1]	0.21	Pinfish[1]	0.41
	Hours fished = 785.5		Hours fished = 1,922.5	
South Texas	Red snapper	1.39	Red snapper	1.77
	Red drum	0.81	Spotted seatrout	1.09
	Spotted seatrout	0.30	Sand seatrout	0.64
	Seatrout	0.21	Seatrout	0.63
	Sheepshead	0.08	Red drum	0.44
	Ladyfish[1]	0.04	Atlantic croaker[1]	0.25
	Warsaw grouper	0.01	Gray triggerfish	0.20
	Hours fished = 76.5		Greater amberjack[1]	0.18
			Bluefish[1]	0.09
			Sheepshead	0.06
			Hours fished = 351.0	

[1]Species change from 1982 to 1983.

species. Area comparisons of the top ten species caught by different fishing methods showed remarkably small differences in composition between 1982 and 1983 even though effort increased almost fourfold (Tables 12 and 13). Species CPH between areas during the 2-year period, however, did change for each fishing method. For example, dolphin made up 45.4 percent of the total troll catch in 1982 but only 21.4 percent in 1983. We further noted that in 1983, dolphin CPH was lower within each comparable area from the 1982 survey. Does this mean an overall decline in dolphin populations off the southeastern United States? These values may or may not be significant. Only the continued collection of this type of data will have the potential to indicate abundance trends.

As previously pointed out, difficulties in analyzing marine recreational catch data are numerous. For example, the highly migratory patterns of coastal and oceanic pelagic fishes make annual surveys difficult to interpret. Multiple-year

surveys, on the other hand, using a small segment of the recreational fishery (charterboats), can contribute to the management of these fisheries by establishing long-term data sets which reflect the relative abundance of any species in time and space.

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Fishery Management Council Appointments Announced

Appointments to serve on the eight Regional Fishery Management Councils have been announced by U.S. Department of Commerce Secretary Malcolm Baldrige. The appointments are for 3-year terms which began 11 August 1985.

Named to the Caribbean Fishery Management Council was Stephen A. Monsanto, Auditor, Post Audit Division, Virgin Islands' Legislature, St. Thomas, V.I. The Caribbean at large seat appointment was to be announced at a later date.

Members reappointed to the Gulf of Mexico Fishery Management Council were Walter W. Fondren, III, Fondren Foundation, Houston, Tex.; Dayton M. Graham, President, Deep Sea Foods, Inc., Graham Charter Fishing, Inc., and Deep Sea Boat Builders, Inc., Bayou La Batre, Ala.; Alex M. Jernigan, former Council Chairman, consulting engineer, Islamorada, Fla.; and Sherman L. Muths, Jr., attorney, Gulfport, Miss. The newly appointed member is "Tee John" Mialjevich, Jr., commercial shrimper, Delcambre, La.

South Atlantic Fishery Management Council members reappointed were Allen F. Branch, past Chairman and Vice Chairman of the Council, owner and operator of marinas and fish camps, Midway, Ga.; and Gregory S. McIntosh, Jr., President, McIntosh Marine, Inc., Ft. Lauderdale, Fla. New members are Elaine W. Knight, General Manager, Knight Seafood, Brunswick, Ga.; and Ernest A. Carl, Deputy Secretary, North Carolina Department of Natural Resources and Community Development, Chapel Hill, N.C.

Appointed to the Mid-Atlantic Fishery Management Council were John H. Burger, President, Burger Construction Co., Dover, Del.; Alex B. Carlson, Jr., founder, Carlson's Fisheries, Manasquan, N.J.; H. R. Humphreys, Jr., Chairman of the Board and CEO, Standard Products Co., Inc., Kilmarnock, Va.; and Frances E. Puskas, part owner, Barnegat Light Yacht Basin and Viking Village Fishing Dock, Barnegat Light, N.J.

Appointed to the New England Fishery Management Council were Patrick L. Carroll, III, Chairman "Bunker Boat Committee", Fairfield, Conn.; James Costakes, General Manager, Seafood Producers Association, New Bedford, Mass.; Gail Johnson, joint owner, swordfish vessel, South Harpewell, Maine; Lester B. Smith, President, Lester Smith Color Productions, Natick, Mass.; Robert D. Smith, Liaison for Regulatory Affairs, Point Judith Fishermen's Cooperative Association, Inc., Narragansett, R.I.

Appointed to the North Pacific Fishery Management Council were James O. Campbell, President, Alaska Division, Spenard Builders Supply, Inc., Anchorage, Alaska; Oscar Dyson, commercial fisherman, Kodiak, Alaska; Rudy A. Peterson, commercial fisherman, Seattle, Wash.

Appointed to the Pacific Fishery Management Council were David N. Danbom, commercial fisherman, Moss Landing, Calif.; Allan L. Kelly, Executive Director, Oregon Wildlife Heritage Foundation, Portland, Oreg.; Jerry L. Thomas, Vice President, Eureka Fisheries, Inc., Fields Landing, Calif.; William F. Yallup, Chairman, Fish and Wildlife Committee, Yakima Indian Nation, Toppenish, Wash.

Appointed to the Western Pacific Fishery Management Council were Louis K. Agard, Jr., commercial fisherman, Honolulu, Hawaii; Roy P. Duenas, General Manager, Port Authority of Guam, Piti, Guam; Melvin D. Makaiwi, part owner, Star of the Sea Fisheries, Inc., Pago Pago, American Samoa.

The eight Fishery Management Councils were established in 1976 when Congress passed the Magnuson Fishery Conservation and Management Act. The Councils prepare plans to manage the marine resources out to 200 miles off the United States' coastline beyond state waters. The members appointed by the U.S. Commerce Department Secretary are selected from names submitted by the state governors. Council members also include representatives from each state marine resource department, the U.S. Coast Guard, U.S. Fish and Wildlife Service, U.S. Department of State, Marine Fisheries Commissions, and the National Marine Fisheries Service Regional Directors.

NOAA Establishes Estuarine Office

The National Oceanic and Atmospheric Administration (NOAA) has established the Estuarine Programs Office (EPO) to coordinate estuarine research and monitoring among NOAA, other Federal and state agencies, and research institutions. The EPO director is John B. Pearce.

Pearce said U.S. estuaries have undergone dramatic changes in the past century. New estuarine-related science, technology, and productivity have benefited the environment, but the consequences of progress and change have caused serious problems in the estuarine ecosystems, he said.

These problems include decreased water quality, declines in fishery catch, near extinction of some species, and loss of protective, spawning, feeding, and nursery habitats. The EPO will function as an advocate for long-term commitment to the restoration, protection, and conservation of living marine resources and fisheries habitats.

Initially, the EPO concentrated its activities in Buzzards Bay, Long Island Sound, Narragansett Bay, Puget Sound, and the Chesapeake Bay. It has interagency agreements with the Environmental Protection Agency, other Federal agencies, coastal states, and academic institutions to encourage development of

estuarine study plans.

The office has held several estuarine seminars for scientists and managers to identify important issues for study in Narragansett Bay, Delaware Bay, and Long Island Sound. EPO's plan to study the Chesapeake Bay includes observing living marine resources, improving fisheries statistics from data acquired by bay-wide sources, and evaluating effects of oxygen depletion on marine life. Pearce said, "Through these coordinated efforts, the Chesapeake Bay and all of our estuaries will be restored, protected, and used appropriately for our society and future generations."

Fishing Pressure Grows on Atlantic Cod Stocks

More Atlantic cod, *Gadus morhua*, are landed in the New England groundfish fishery than any other two groundfish species combined. Cod landings during 1980-83 averaged 51,000 metric tons (t), or 112 million pounds, annually, the highest for any 4-year period in this century. In 1984, however, U.S. landings from the Georges Bank and the Gulf of Maine cod stocks declined to 43,600 t (96 million pounds), 14 percent less than in 1983, and the lowest annual catch since 1979.

NMFS Northeast Fisheries Center scientists expected landings to decline further in 1985. Analyses of commercial fishery and research vessel information indicated that fishing mortality on both cod stocks had markedly increased and was at near-record high levels. The number of days fished for cod by the U.S. otter trawl fleet reached historically high levels in both stock areas during 1984 (Fig. 1). While fishing effort was increasing, the abundance of cod (catch per day fished for trips in which cod comprised 50 percent or more of the trip weight) declined by 30 percent on Georges Bank and by 35 percent in the Gulf of Maine from 1983 levels.

The estimate of abundance for the Georges Bank stock in 1984 was the lowest since 1965 (when such records were first kept) while the estimate of abundance in the Gulf of Maine for 1984 was the third lowest observed and lower than any value since 1983. NEFC research vessel survey data showed comparable trends. The estimates of abundance from such research data for both stocks in 1984 were among the lowest ever obtained.

Since 1981, fishing mortality on cod has doubled on Georges Bank and has increased fourfold in the Gulf of Maine. In both stocks, recent fishing mortality rates are the highest in over 20 years, exceeding even those observed when foreign fleets were exploiting the New England cod stocks in the mid-1960's. The current levels of fishing mortality are much in excess of the levels which would produce the maximum yield.

Although abundance of scrod cod on Georges Bank will improve in 1985 due to recruitment of an above-average year class of cod hatched in 1983, the abundance of this year class is not as strong as those produced in 1971, 1975, and 1980 which contributed to large increases in commercial landings.

The recent increases in fishing pressure on the New England cod stocks have resulted from increased efforts directed specifically toward cod as other groundfish resources (haddock, redfish, yellowtail flounder) have declined. Should fishing pressure remain at current levels, further declines in cod abundance are anticipated.

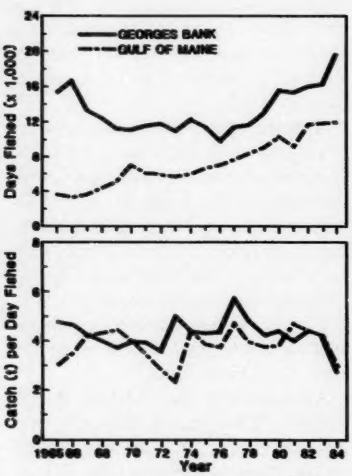

Figure 1.—U.S. otter trawl effort (thousands of days fished) and catch per unit of effort (t/day fished) for Atlantic cod from Georges Bank and the Gulf of Maine, 1965-84.

Foreign Fish Harvest Below 5-Year Average in U.S. 200-Mile FCZ

Foreign nations caught more fish in 1984 within the U.S. 200-mile fishery conservation zone than in the year before but less than the average for the preceding 5 years, according to the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). NOAA's National Marine Fisheries Service said foreign countries harvested 3 billion pounds of fish and shellfish, compared with 2.9 billion pounds in 1983, a 4 percent increase.

However, the harvest was 11 percent below the average for the preceding 5 years—3.4 billion pounds. Meanwhile, the U.S. share of fish taken from the conservation zone increased. It hit 50 percent of all fish taken last year, up from 47 percent in 1983, and the highest since the 200-mile fishery conservation zone was established in 1977. In the late 1970's U.S. fishermen were harvesting only about one-third of all the fish taken from the fishery conservation zone.

U.S. fishermen landed 6.4 billion pounds of edible and industrial fish and shellfish, down slightly from 1983, but close to the record domestic landings of 6.5 billion pounds in 1980. About 2.9 billion pounds were caught in the fishery conservation zone.

Joint-venture harvests by American fishermen, who sell their catches at sea to foreign processing vessels, continued upward in 1984. Last year almost 1.5 billion pounds of fish, valued at $79 billion, were loaded onto foreign vessels. This represents a substantial increase over 1983 when American joint ventures sold 959 million pounds of fish worth $51.2 million. Japan continued to be the leading harvester in the U.S. fishery conservation zone, catching 2.1 billion pounds, or 69 percent of the foreign total. South Korea, with 605

million pounds, 20 percent of the catch, was second. Other foreign fishing fleets included those from Canada, Spain, and Italy. About 97 percent of the total foreign fish harvested was taken from the Gulf of Alaska and the Eastern Bering Sea. Less than 100 million pounds were taken by foreign fishing vessels from the Northwest Atlantic.

Sea Scallops Decline; Fishing Patterns Shift

Preliminary 1984 commercial sea scallop landings data indicate that the total 1984 scallop catch (U.S. and Canada) from the Georges Bank, Mid-Atlantic, and Gulf of Maine regions declined to 9.900 metric tons (t) (meats), the lowest annual harvest in 10 years. Georges Bank landings in 1984 (4,800 t) were the lowest since 1948, with the U.S. catch the lowest since 1976 and the Canadian catch the lowest since 1958 (Fig. 1). U.S. 1984 landings from the Mid-Atlantic (4,000 t) increased 24 percent from 1983 while U.S. Gulf of Maine landings (800 t) declined 11 percent from 1983.

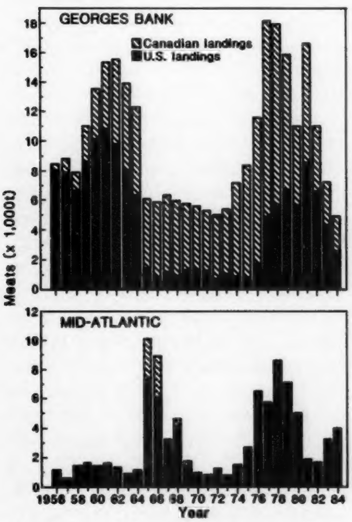

Figure 1.—Total U.S. and Canadian commercial sea scallop landings (metric tons, meats) from Georges Bank (NAFO Subdivision 5Ze) and the Mid-Atlantic region (NAFO Statistical Area 6), 1956-84.

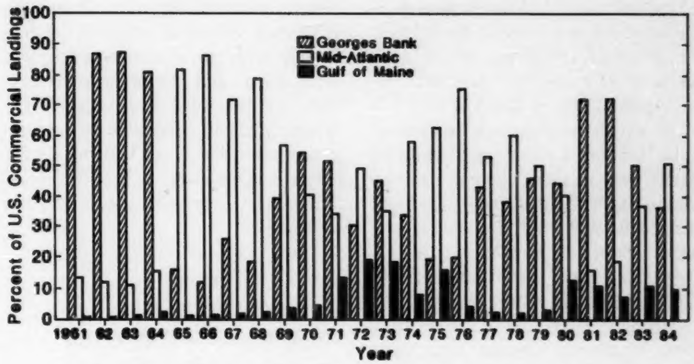

Figure 2.—Percentage distribution of total annual U.S. commercial sea scallop landings (metric tons, meats) from Georges Bank (Area 5Ze), the Mid-Atlantic (Area 6), and the Gulf of Maine (Area 5Y), 1961-84.

For the first time in 5 years, more catch was taken by the U.S. fleet from the Mid-Atlantic region that from Georges Bank (4,000 t vs. 2,850 t), reflecting a change in fishing patterns (Fig. 2). Substantial increases in fishing effort occurred in the Mid-Atlantic region during 1984. Both the number of trips and the days fished per trip were higher in 1984 than in 1983.

Data from the NMFS's annual series of summer sea scallop research vessel surveys show that scallop abundance in almost all areas fished by the U.S. fleet has declined in recent years. The 1984 survey results indicate that, with the exception of the Northern Edge and Peak region of Georges Bank (in mostly Canadian waters) and the New York region (off Long Island and New Jersey), sea scallop abundance remains at historically low levels.

The current assessment indicates that fishing mortality continues at near record high levels and that the fishable stock depends upon the recruitment of new year classes. Recruitment of the 1981 year class in the 1984 survey was low in all areas except on the Northeast Peak and in the New York Bight. Given the disparity in scallop abundance among the various offshore regions and the exclusion of U.S. fishing activity on the Northeast Peak in areas east of the World Court boundary line, the U.S. scallop fleet was expected to continue concentrating much of its activity in the Mid-Atlantic region during 1985.

Drift Bottle Makes Long Ocean Journey

A drift bottle released from the NOAA ship *Townsend Cromwell* more than 11½ years ago on 4 February 1973 at lat. 01°48′N, long. 157°04′W near Christmas Island was recovered on 15 June 1983 over 4,600 miles away due west on a beach on the northeast coast of Mindanao near lat. 09°48′N, long. 125°29′E in the Philippines, reports Richard S. Shomura, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory.

The bottle was reportedly found by Cesar L. Cabrera at White Beach in Cagwait, a town in Surigao Sur, Mindanao, a southern Philippine island. It is

not clear why the finder (or sender) waited over a year to mail the card to the Honolulu Laboratory (the envelope was postmarked 12 September 1984); the return address was: 4th Mun. Circuit Trial Court of Cagwait-Bayabas, Cagwait, Surigao del Sur.

This particular drift bottle was one of 840 released a few miles north, east, and south of Christmas Island on 4 February 1973, and was part of an experiment devised by Richard A. Barkley, an oceanographer then on the staff of the Honolulu Laboratory, to study the pattern of surface currents around oceanic islands. Christmas Island was selected for this study because it provided a relatively simple situation: A single small island that had no other intruding islands located "upstream" in the strong regular flow of the westerly North Equatorial Current. One bottle was recovered at sea the next day after it had traveled around the north coast of the island and then west. Twelve bottles were recovered from the windward beach on Christmas Island on 11 and 12 February 1973. Other areas of Christmas Island, and other islands in the Line Islands group (Fanning, Washington, and Palmyra) were searched but no other bottles were found.

In its westward travel in the grasp of the North Equatorial Current the bottle must have passed by numerous islands in the Equatorial Pacific Ocean on its way to Mindanao. For about 1,500 miles in the area immediately west of Christmas Island there are relatively few islands. However, further west in the path the bottle presumably took are the many Gilbert Islands, the Marshalls, Federated States of Micronesia, and the Republic of Palau.

Although the time elapsed between the time of release and recovery was over 10 years, Shomura speculated that the bottle may have been lying undiscovered on the Mindanao beach for a number of years, especially if White Beach is in a remote, relatively uninhabited part of Mindanao. Other drift experiments have shown that bottles released near the Equator in the central Pacific Ocean traveled at speeds of more than 36 miles a day, so it is possible that this bottle could have made the journey of over 4,600 miles in about 128 days. It is also possible, of course, that although the bottle was under the primary influence of the North Equatorial Current, it could also have been affected by local currents near islands and thus taken much longer to reach the Philippines. So even though no information was obtainable on the speed of the drift for this bottle, the direction of drift was determined, and conforms to what is known of the surface currents in the Equatorial Pacific. But perhaps more interesting is what is not known: All the possible meanderings of the bottle in its long journey from Christmas Island to Mindanao.

Underutilized Fishery Resources of California

In 1981, about 8,500 vessels (most under 5 net tons) and 19,000 persons were engaged in commercial fishing in California. However, many "superseiners" are also based in the State and some large trawlers have also entered the fleet.

Over 100 species of fish are caught by California commercial fishermen, but quite a number of others are not fully utilized. Therefore, the staff of the Underutilized Fishery Resources Task, Tiburon Laboratory, NMFS Southwest Fisheries Center, 3150 Paradise Drive, Tiburon, CA 94920 has prepared a looseleaf "Guide to Underutilized Species of California" as Administrative Report T-83-01.

The report contains a brief description of California's fisheries and the fishing gear and methods. Most of the species included are considered to be underutilized and therefore underharvested; many are also very similar to species utilized in other countries and the guide provides much pertinent information useful to foreign buyers or for those wanting to market new species in foreign countries. Data for each species include brief description of life history, distribution, abundance, and the present fishery, if any, and the authors also point out some new processing or marketing ideas which may be of commercial significance.

Species listed include shortbelly rockfish, *Sebastes jordani*; Pacific sanddab, *Citharichthys sordidus*; jack mackerel, *Trachurus symmetricus*; ocean sunfish, *Mola mola*; ocean whitefish, *Caulolatilus princeps*; night smelt, *Spirinchus starksi*; basking shark, *Cetorhinus maximus*; ratfish, *Hydrolagus colliei*; groundfish roe; market squid, *Loligo opalescens*; king crab, *Paralithodes californiensis*; Tanner crab, *Chionoecetes tanneri*; rock crabs, *Cancer productus*, *C. antennarius*, and *C. antonyi*; krill, *Euphausia pacifica*; Kellet's whelk, *Kelletia kelletii*; giant Pacific octopus, *Octopus dofleini*; spiny dogfish, *Squalus acanthias*; sea cucumber, *Parastichopus californicus* and *P. parvimensis*; sheep crab, *Loxorhyncus grandis*; and ridgeback prawn, *Sicyona ingentis*. In addition, six color plates illustrate 19 of the species. Further information on the report and the species is available from the Task Force in Tiburon.

Offshore Tagging Shows Maine Lobster Movements

Results from the first 18 months of a 3-year joint State of Maine-National Marine Fisheries Service (NMFS) lobster tagging and undersea (submersible) research program have been compiled, according to the NMFS Northeast Fisheries Center. The purpose of this program is to provide information on abundance, migration, growth, and stock interaction between inshore and offshore lobsters in the Gulf of Maine, and to better understand the effects of the expanding offshore fishery on the inshore stocks of lobsters.

Of primary interest is the role of the central Gulf of Maine lobster in providing recruitment to the coastal areas. Does the offshore Gulf of Maine lobster population represent an important part of the broodstock for the inshore population? Do the offshore Gulf of Maine deep water basins provide important habitats for a potential broodstock?

In July 1984, 917 lobsters were tagged and released in Area "A" (Jordan Basin - 643), Area "C" (Cashes Ledge - 203), Area "D" (Jeffreys Ledge - 41) and Area "E" (Bank Comfort - 30) in

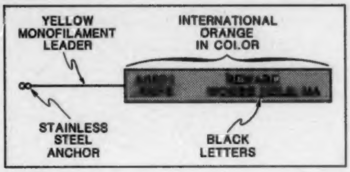

Figure 1.—Lobster tag.

the Gulf of Maine. Lobsters ranged in size from 2½ to 7¼ inches carapace length (CL); 60 percent females, 40 percent males. The average lobster tagged was 4⅜ inches CL. Between July 1984 and July 1985, 226 tagged lobsters were recaptured; 19 were removed from the population (returned to NMFS) and 207 were recaptured between 1 and 4 times and released back into the population.

Movements from Cashes Ledge, Jeffreys Bank, and Bank Comfort were mainly toward the Maine coast or parallel to the shore. The maximum distance traveled was by a female lobster which covered 81.5 n.mi. in about 109 days. The average distance traversed by these 19 recaptures was 35 n.mi., averaging 0.5 n.mi. per day. One recapture averaged 1.13 n.mi. per day.

The remaining 207 recaptures, all but 10 released by a single offshore fisherman from Maine at Jordan Basin, were made in relatively close proximity to the original area of capture and tagging (less 10 n.mi.). However, since 18 Sept. 1984, no recaptures were made in the Jordan Basin areas because the offshore Maine fisherman had to move his gear to the west when the new U.S.-Canadian boundary line was finalized.

Of the 548 female lobsters tagged and released in July 1984, 133 (24.3 percent) were berried. The average CL of these females was 4¾ inches, 1/4-inch above the average size of all females. Recaptured females had both released eggs and extruded eggs between the time of tagging and recapture.

These preliminary results indicate a high removal rate in the vicinity of the tag and released areas with either an apparent tendency of tagged lobsters to remain in areas where there are a large number of lobster traps or a slow rate of migration through the tagging areas. Of the 379 lobsters recaptured from the 1983 releases and 226 lobsters recaptured from the 1984 releases, only 83 and 16, respectively, were captured outside of a 10 n.mi. radius from the release locations. It is evident from the decline in the recapture rate in the vicinity of the release areas and the distribution of recapture locations that the original stock of tagged lobsters had dispersed over a very broad area.

On Saturday, 29 June 1985, the NMFS ended 6 days of tagging lobsters in the Gulf of Maine, with about 1,000 lobsters marked with international orange tags (Fig. 1) and released in the western part of Jordan Basin in about 100 fathoms. Fishermen who catch any of the tagged lobsters can claim a $5.00 reward plus the current landed value of the lobster by keeping the lobster alive or frozen; recording the tag number, the date and location of capture, the carapace length, and any general comments about the lobster; and notifying the nearest NMFS port agent; or, by mailing the tag and above information to Tom Meyer, National Marine Fisheries Service, Woods Hole, MA 02543. This is the final year of the 3-year lobster tagging program between Maine's Department of Marine Resources and NMFS's Northeast Fisheries Center.

Kraft Markets Federally Inspected Fish Products

The Kraft, Inc. Foodservice Group[1] will begin marketing Federally inspected fishery products as part of its participation in the U.S. Commerce Department's voluntary national seafood inspection program. The Group is the nation's fifth largest distributor of food service products. Thus, in contracting to have its seafood products inspected and graded by the Commerce Department's National Marine Fisheries Service, it has become the largest food service distributor to take part in the Federal seafood inspection program. The voluntary program is carried out by the NMFS to offer processors and retailers impartial and certified inspection of fresh, frozen, canned, and cured fish and shellfish. The "Packed Under Federal Inspection" mark and the "U.S. Grade A" quality mark on fishery products assure buyers of safe, wholesome, and properly labeled products certified by Federal inspectors.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Horseshoe Crab Studied

Fisheries for horseshoe crabs for bait and biomedical purposes are growing, reports the NMFS Northeast Fisheries Center (NEFC). In fact, horseshoe crabs may be overfished in some areas. To establish the biological basis for managing horseshoe crabs—should that be needed—scientists from the NEFC and Fordham University initiated a joint study of the species' distribution, abundance, feeding, and growth.

Historical data from the Center's bottom-trawl surveys is providing information on trends in distribution and abundance. Recent data from the surveys will provide information on feeding by this predator on clams, scallops, etc. One of the more unusual efforts will be trying to determine the age of limpets growing on the shells of horseshoe crabs as a way of indirectly determining how long the crabs themselves can live.

Fish Prices by Phone

The National Marine Fisheries Service has installed an automatic telephone message center at Rockland, Maine. This provides callers with the Boston New England Fish Exchange daily landings, fish auction prices, and the New Bedford sea scallop landings and ex-vessel prices. The new 24-hour telephone service may be reached by calling Rockland (207) 596-0190.

Automatic telephone message centers are also available in: Portland, Maine (207) 780-3340; Gloucester, Mass. (617) 283-1101; Boston, Mass. (617) 542-7878; New Bedford, Mass. (617) 997-6565; New York, N.Y. (fresh fish prices) (212) 620-3577; New York, N.Y. (frozen fish prices) (212) 620-3244; and Hampton, Va. (804) 723-0303.

The Fisheries and Fishery Trade of the People's Republic of China

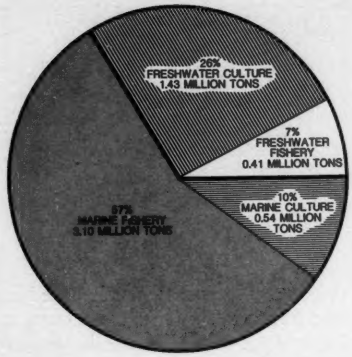

Figure 2.—China's total 1983 fisheries catch was 5.48 million t.

Introduction

The People's Republic of China (Fig. 1) is the world's third largest fisheries producer, after Japan and the Soviet Union (see related article on next page). Although Chinese fishermen caught nearly 5.5 million metric tons (t) in 1983, and an estimated record-high 6.0 million t in 1984, China's large coastal fishery is generally believed to be overexploited.

China, therefore, began studying distant-water fishing as a possible alternative to offset coastal overfishing. China has also increased its fish and shellfish culture, thus enabling it to continue as the world's leading aquacultural producer.

China is a net exporter of fishery products, with principal markets being Japan, Hong Kong, and the United States. In 1983, China shipped nearly $11.9 million worth of fishery products to the United States—mostly shrimp and other high-valued shellfishes. Because China plans to increase cultured fish and shellfish production, many observers believe that its fishery exports will also expand. Conversely, China was the fourth largest Asian market for U.S. fishery products—mostly frozen herring—in 1983.

Fisheries Catch

China's Bureau of Aquatic Products (BAP) estimates that China's 1983 fisheries harvest totaled nearly 5.5 million t (Fig. 2, Table 1), an increase of almost 10 percent (mostly from aquaculture) compared with the 1982 fisheries harvest of 4.9 million t. BAP estimated that the 1984 fisheries harvest was 6.0 million t, an increase of 11 percent over the 1983 harvest.

China's fisheries catch increased significantly after its fishery development policy was revised in 1979. This policy promotes improved management of wild fisheries and the expansion of marine and freshwater aquaculture. China hopes to realize the full potential of its fisheries by continuing to implement and improve fisheries management plans and expanding aquaculture production efforts.

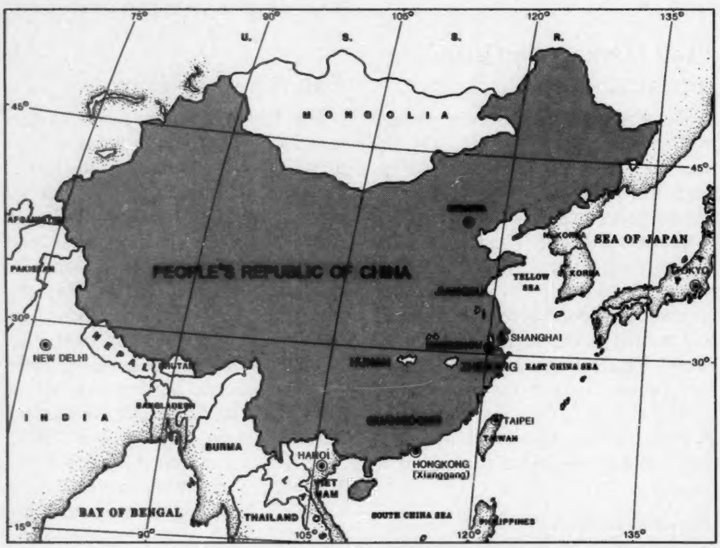

Figure 1.—The People's Republic of China.

Freshwater

China harvests freshwater fish and shellfish from both the wild and from fish culture projects. From 1979 to 1984, the freshwater catch doubled from 1.1 million t to about 2.2 million t, or 17 percent more than the 1.8 million t harvested in 1983. As in 1983, more than 80 percent of China's 1984 freshwater fish harvest was farmed. China was able to greatly increase its 1984 production because more than $78 million was invested in fish farming by collectives, other enterprises, and many individuals in the provinces of Guangdong, Hunan, and Jiangsu.

Capture Fishery

China's harvest of fishes totaled 0.4 million t in 1983, only 7 percent of the country's total fisheries catch and most-

Table 1.—China's fisheries catch, by quantity, 1979-84.

Fishery	Catch (1,000 t)					
	1979	1980	1981	1982	1983[1]	1984
Freshwater	1,115.9	1,239.9	1,373.5	1,562.0	1,843.0E	2,150.0E
Marine	2,938.4	2,995.4	3,003.5	3,364.7	3,614.0E	3,850.0E
Total	4,054.3	4,235.3	4,377.0	4,926.7	5,457.0E	6,000.0E

[1]E = Preliminary estimate.

ly various carps. Because this fishery cannot meet the domestic demand, China is promoting freshwater fish culture.

Culture

China is the world's largest producer of farmed freshwater fish, and used more than 3.0 million hectares in 1983 for fish culture. Still, the BAP estimates that the country could potentially employ nearly 5.0 million hectares of freshwater ponds. Grass carp, black carp, big head carp, mud carp, and tilapia are the principal species cultured. Most of the harvest is consumed domestically.

China's freshwater culture owes its success to several factors. Foremost, is the policy of making multiple use of water resources. While reservoirs and smaller farm ponds may be constructed primarily for irrigation or domestic use, they are simultaneously used for fish production.

Secondly, China integrates most of its freshwater fish farming with animal husbandry and agriculture. For example, agricultural crops are used to feed farm animals or poultry, whose manure is then collected to fertilize fish ponds. The humus that accumulates in the fish ponds is then recycled back to the cropland[1].

Thirdly, mixed species cultivation, or "polyculture," is widely practiced with great success. Finally, most fish growing regions of China have communes that specialize in hatchery production and rearing of fry for distribution to numerous growout ponds at other communes. The personnel at these "hatchery" communes are accomplished in such fields as induced spawning, selective breeding, larval rearing, disease prevention and treatment, and nutrition —areas normally thought to require highly specialized training in the West.

Provincial and municipal governments also promote freshwater fish culture. Beijing's Municipal Government is doing so especially because of unstable supplies of marine fishery products. Individuals, schools, Government agencies, army units, and other organizations are also being encouraged to culture freshwater fishes. Beijing's banks will extend credit for building ponds and developing feed processing methods, and municipal officials plan to reduce or remit taxes on production and sales of cultured freshwater fish for an unknown period. Organizations that leave suitable freshwater ponds unused in their vicinities are reportedly fined.

Marine

China's marine fisheries catch (3.6 million t in 1983) combines the harvests from mariculture, coastal fisheries, and distant-water fisheries. Most of the catch continues to be harvested by trawling (mostly pair trawling) or seining in coastal waters. The Chinese Government realizes that this coastal fishery is overexploited and is taking measures to protect and stabilize it, while studying distant-water fishing opportunities in the Pacific and Indian Oceans.

The Chinese reportedly manufacture their own engines, associated machinery, stern gear, winches, and windlasses. All electronic fishing aids and navigation equipment, apart from sonar, are also produced domestically. The Chinese manufacture their own netting, lines, ropes, floats, and hooks. Polyethylene appears to be the principal synthetic material used for ropes, but some nylon is used in purse seines.

China has expressed interest in Western fisheries technology, and the China Marine Industries Corporation and various Government fishery agencies organized "Fishery China '85", the Second International Fishery and Processing Exhibition, 16-21 November 1985, in Hangzhou, Zhejiang Province. Chinese officials attending the Exhibition were empowered to purchase Western fisheries technology.

Capture Fishery

Wild-caught fishes accounted for most of China's marine harvest in 1983 —nearly 3.1 million t, or almost 60 percent of China's total fisheries catch. Much of China's marine catch is made by 17 state-owned fishing corporations, of which the largest two are the Shanghai Marine Fisheries Company and the Dalian Marine Fishery Company. The predominant species landed by China's marine fishermen include filefish, hairtail, chub mackerel, yellow croaker, Spanish mackerel, and herring.

[1]Chinese officials believe that integrated fish culture is the most effective and efficient way to farm freshwater fish. Nevertheless, some fish farmers do not use integrated methods.

China Ranks Third in Fish Harvest

China's total fish catch in 1984 was 6 million metric tons (t), 500,000 t more than in 1983 and the third largest catch in the world, according to the New China News Agency. By 1990, China plans to have 60 percent of its catch (about 5 million t) in canned, processed, and frozen food sales.

Currently, 240 national fish processing plants produce 1,480,000 t of fish products. And, a national fisheries processing center is scheduled for construction in Shanghai to produce canned goods for major northern Chinese metropolitan areas. China also has 370 nationally operated freezing plants of various sizes. And, while commercial freezer construction has increased in recent years, small-scale, coastal commercial freezer production does not exceed 30,000 t.

China has increased its efforts to develop a distant-water fishery. In 1984, it entered into joint venture agreements with Japan, Mauritius, New Zealand, Somalia, and Sri Lanka, and may seek other joint venture partners in the future (see related articles on pages 77 and 83). China has also purchased several used seiners and trawlers from Japanese companies, as well as fishing gear and net-making equipment, and was reportedly attempting to negotiate the purchase of other fishing vessels from Japan. However, the Japanese may be reluctant to export more vessels to China for fear of competition with Japanese fishermen in the North Pacific.

China has also expressed an interest in obtaining fishing allocations within the U.S. 200-mile Exclusive Economic Zone (EEZ), and a delegation had an exploratory meeting with representatives of the U.S. Departments of State and Commerce in September 1984 to discuss fishing off Alaska. U.S. representatives briefed them on the status of fishery stocks off Alaska and on the need to negotiate a governing international fishery agreement (GIFA) before China could apply for allocations. U.S. officials also explained the rules and regulations that apply to foreign fishing vessels operating in the U.S. EEZ. Further talks were held in November in Beijing, and more were planned for Spring 1985.

Culture

China's mariculture production was a record-high 0.5 million t in 1983; sea cucumber, scallop, abalone, shrimp (mostly *Peneaus orientalis*), and various aquatic plants were the primary species (Table 2). Mariculture conditions in China are considered excellent. The country has a lengthy coastiine with many estuaries, shoals, and mudflats ideal for fish farming. BAP estimates the saltwater culture capacity at 1.3 million hectares. Although recent data are unavailable, China reportedly exported $40 million worth of cultured marine fishery products in 1981.

Table 2.—Some of the marine species cultured in China.

Category	English name	Scientific name
Fish	Giant perch	*Lates calcarifer*
Shellfish	Blue mussel	*Mytilus edulis*
	Razor clam	*Sinonovacula constructa*
	Oysters	*Ostrea plicatula*
		Crassostrea gigas
		C. talienwhanensis
	Abalone	*Haliotis discus hannai*
	Scallop	*Chlamys farreri*
	Oriental shrimp	*Penaeus orientalis*
	Banana shrimp	*P. merguiensis*
	Crabs	N/A[1]
Other	Sea cucumber	*Stichopus* spp.
	Kelp	*Laminaria japonicus*
	Giant kelp	*Macrocystis pyrifera*

[1]N/A = Not available.

Fisheries Trade

China does not release detailed import and export statistics, making accurate fisheries trade analysis difficult. China reportedly imports few fishery products; instead, observers believe that it is trying to expand its fishery exports to earn foreign exchange.

Largest Market

Hong Kong is believed to be the largest market for Chinese fishery products, but it is not known how much Hong Kong re-exports elsewhere[2]. Japan is another large market for Chinese fishery product exports (Table 3) and has received more than 30,000 t annually since 1979—mostly shrimp, clams, crabs, jellyfish, and seaweed, and lesser amounts of eel, Spanish mackerel, and herring. Because China plans to increase marine fish and shellfish culture, many observers believe that its fishery exports will also expand.

Policy Changes

The Chinese Government has decided to relax the rigid control over its fishing industry and to promote fish farming to ease the nationwide shortage of fishery products. The decision to revise the fisheries marketing policy was made by the Communist Party's Central Committee, together with the State Council, and is aimed at quadrupling China's fisheries production and tripling per capita fishery consumption by the end of this century.

The new policy abolishes State purchase quotas for fishery products and establishes a free market in its place. Fish prices will now be set according to floating market rates, provided that the prices do not exceed or fall below an unspecified (at this writing) price range for the various species. When prices become too high or too low, the Government will regulate them either by buying the products or by increasing production.

The new marketing policy will be combined with reforms in China's management of the fishing industry aimed at simplifying fisheries administration and leaving more decisions to various independent provincial and municipal fishery corporations and cooperatives. These independent entities will then be responsible for their own profits and losses.

U.S.-China Fisheries Trade

The United States and China first began direct fisheries trade in the early 1970's. Although currently small, the potential of this trade is great. In 1983, fisheries trade between the United States

[2]Hong Kong imported 119,000 t of fishery products in 1982 and more than 124,000 t in 1983, over 50 percent of which is believed to have come from China. Hong Kong does not break down its fishery import statistics by country so precise figures are unavailable.

China's Aquaculture, 1984

China's aquaculture industry reportedly produced fish and shrimp totalling 2,450,000 metric tons (t) in 1984, with the marine culture sector totalling 600,000 t. The increase was due in part to an increase in fish farming area to 3,470,000 hectares, with 130,000 hectares of otherwise untillable land being brought under aquaculture. In addition the Provinces of Guangdong and Jiangsu received 100 million yuan in financing for fish pond renovation in 1984 and the China Ministry of Agriculture, Pastures and Farming provided aquaculture training courses in the Provinces of Jiejiang, Hunan, and Anwei. Farms specializing in fish and shrimp production also increased and group fish farming contracts encouraged by the government grew to 2,070,000 in 1984.

Table 3.—China's fishery exports to Japan, by species and quantity, 1979-84.

Category and species	Exports (t) 1979	1980	1981	1982	1983	1984[1]
Finfish						
Eel	10.5	98.0	298.8	444.8	744.8	817.7
Spanish mackerel	1,517.4	2,586.7	2,133.0	1,526.2	774.3	687.3
Herring	857.8	862.9	994.1	451.5	915.9	561.9
Puffer or blowfish	11.0	24.5	114.3	154.2	185.8	209.2
Horse mackerel			144.8	31.6	62.0	62.3
Croker	55.9	51.2	284.3	109.8	118.3	47.6
Pollock		3.7		12.0	50.5	14.2
Hairtails	28.9	30.7	53.9	17.6	30.8	12.5
Sea bream	4.5	2.5	18.4		7.8	5.1
Salmon	9.0	7.1	17.8		197.6	
Tuna	0.5	22.0	0.5	76.4	1.7	
Swordfish			0.4	1.0		
Sardine		0.3	0.9	0.4		
Other	1,001.3	1,863.2	3,357.7	4,161.1	3,633.4	4,692.0
Subtotal	3,496.8	5,552.8	7,418.9	6,986.6	6,722.9	7,109.8
Shellfish						
Clam	8,074.8	9,071.5	11,004.1	9,842.5	10,679.3	10,339.4
Shrimp	12,119.2	14,510.2	14,968.4	10,134.0	5,862.2	10,321.9
Crab	648.6	1,241.8	2,771.4	2,523.9	3,599.7	4,505.7
Squid/cuttlefish	857.7	692.3	290.1	560.3	430.9	454.6
Octopus	119.7	91.2	91.7	29.6	29.2	7.0
Lobster	13.3			2.9	4.2	6.7
Other	8,414.3	9,436.4	10,293.1	5,929.6	10,418.9	10,740.1
Subtotal	30,247.6	35,043.4	39,418.8	29,022.8	31,024.4	36,375.4
Other						
Jellyfish	644.0	1,652.5	1,059.3	1,802.5	2,672.9	1,765.3
Seaweed	152.0	790.4	1,421.7	1,852.5	2,311.3	1,716.9
Sea urchin	35.5	86.5	135.1	146.8	174.9	158.3
Misc.[2]		negl.[3]	negl.	negl.		
Subtotal	831.5	2,529.4	2,616.1	3,801.8	5,159.1	3,640.5
Grand totals	34,575.9	43,125.6	49.453.8	39,811.2	42,906.4	47,125.7

[1]Preliminary statistics.
[2]Mostly small pelagic species reduced to fishmeal and oil.
[3]Negl. = negligible.

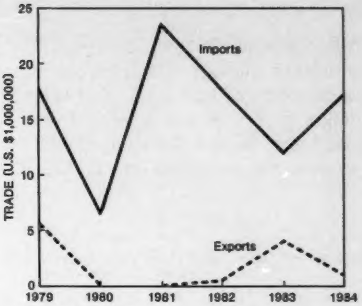

Figure 3.—U.S. fisheries trade with China, by value, 1979-84.

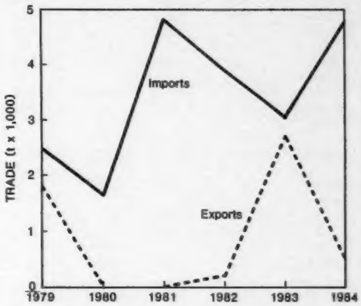

Figure 4.—U.S. fisheries trade with China, by quantity, 1979-84.

and China was nearly $16.0 million and in 1984 it was over $20.8 million (Fig. 3, 4). China's fishery imports from the United States have consisted mainly of herring, while exports to the United States are mostly shrimp and other high-valued shellfishes.

U.S. Imports

China currently supplies less than 1 percent of all U.S. fishery imports. The United States, nevertheless, is one of China's leading markets for fishery products, along with Japan and Hong Kong. Some Chinese-origin fishery products reach the U.S. market through re-export from other Asian countries. In 1984, the United States imported 4,750 t of fishery products directly from China, at a value of $20.2 million. The record high, 4,810 t valued at over $23.7 million, was in 1981 (Fig. 3, 4).

Commodities

In 1984, U.S. imports were mainly frozen shellfish, whole and filleted frozen fish, and canned fish (Tables 4, 5). These commodities have accounted for most of the quantity and value of Chinese fishery shipments to the United States in recent years. Frozen shellfish imports from China have fluctuated because of China's unstable shrimp production. The United States imported 1,877 t of frozen shellfish in 1984, 39 percent more than the 1,142 t imported in 1983.

China's shipments of whole and filleted frozen fish to the United States have fluctuated greatly during the past 5 years. The record year (by quantity) was in 1984, when 1,675 t worth $3.2 million was shipped. The previous record was 1981 when 1,500 t worth $3.3 million was shipped. The United States also imported 553 t of canned fish—mostly mackerel—worth nearly $0.8 million from China in 1984.

Species

Shrimp was by far the most important species imported in 1984 (Tables 6, 7). China's shrimp shipments to the United States decreased during 1982 and 1983 (because of unstable catches and quality control problems), but began to increase in 1984. While shrimp represented only 32 percent of the quantity of fishery products imported from China in 1984, it represented 62 percent of the total import value. Other shellfishes (i.e., scallops and oysters) showed sudden and significant increases in 1984.

The United States imported 1,512 t of shrimp, worth nearly $12.5 million,

from China in 1984, an increase of 42 percent by quantity and 51 percent by value compared with 1983. Most of the imported shrimp was shipped frozen (shell on); the rest was shipped either peeled and deveined, or canned. China generally ships three grades of shrimp to the United States: Superior, good, and marginal.

China's shipments of abalone, clams, crabs, oysters, and scallops to the United States showed a significant increase in 1983, and that trend continued in 1984. Almost 600 t of these high-valued shellfishes worth over $2.5 million, were shipped to the United States in 1984, an increase of 30 percent by quantity and 26 percent by value, compared with

Table 4.—U.S. fishery imports from China, by quantity and commodity, 1979-84. Source: U.S. Census Bureau.

Commodity	U.S. imports (t) 1979	1980	1981	1982	1983	1984
Edible						
Fish						
Frozen						
Whole	[illegible]	536.5	1,506.7	1,381.8	740.3	1,394.4
Fillets	113.8	56.4	57.3	119.0	294.5	280.5
Canned	108.5	325.9	607.8	418.7	459.6	553.1
Cured	51.6	96.8	108.6	182.8	133.3	165.0
Roe	0.5	0.3	negl.	0.1	0.2	0.2
Other[1]	50.9	48.5	67.6	124.9	132.4	192.0
Shellfish						
Frozen	1,448.1	539.2	2,408.0	1,583.4	1,142.4	1,877.0
Canned	46.6	47.9	47.0	49.7	116.8	189.6
Other						46.7
Subtotal	2,516.6	1,651.6	4,802.9	3,860.4	3,019.5	4,698.5
Nonedible						
Fishmeal						20.9
Fish oil				1.3	2.6	
Other	3.3	4.8	6.3	6.1	34.0	27.3
Subtotal	3.3	4.8	6.3	7.4	36.6	48.2
Grand total[2]	2,519.9	1,656.4	4,809.2	3,867.8	3,056.1	4,746.7

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

Table 5.—U.S. fishery imports from China, by value and commodity, 1979-84.

Commodity	U.S. imports (US$1,000) 1979	1980	1981	1982	1983	1984
Edible						
Fish						
Frozen						
Whole	995.5	833.2	3,299.7	2,763.3	1,461.3	2,686.9
Fillets	181.1	108.1	116.2	213.2	519.9	523.3
Canned	203.5	518.0	814.1	691.1	883.2	772.6
Cured	203.3	512.4	471.7	779.9	560.6	619.5
Roe	50.2	33.2	3.4	2.9	24.8	7.2
Other[1]	239.2	209.0	249.5	477.9	356.5	442.8
Shellfish						
Frozen	15,327.5	4,091.3	18,454.0	12,889.3	7,480.5	14,459.3
Canned	279.2	135.4	178.1	214.8	406.0	451.5
Other						65.2
Subtotal	17,479.5	6,440.6	23,586.7	18,032.4	11,692.9	20,028.3
Nonedible						
Fishmeal						10.6
Fish oil				4.9	10.5	
Other	70.9	84.3	138.1	84.4	190.4	201.3
Subtotal	70.9	84.3	138.1	89.3	200.9	211.9
Grand total[2]	17,550.4	6,524.9	23,724.8	18,121.7	11,893.8	20,240.2

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

Table 6.—U.S. fishery imports from China, by quantity and species, 1979-84.

Category and species	U.S. imports (t) 1979	1980	1981	1982	1983	1984
Edible						
Fish						
Mackerel	11.1	110.7	333.4	225.2	173.2	296.4
Flatfish	15.3			10.0	140.1	135.8
Pollock				36.0	36.0	246.6
Groundfish	16.1	27.4	29.3	45.2	35.9	163.1
Pacific cod	0.5		0.2		22.3	6.4
Herring	3.3	2.6	0.2	3.0	0.3	0.5
Sardines	4.4	6.9	1.5	25.6		23.5
Tuna	0.6	3.0	333.0	354.5		213.1
Other	923.8	864.0	1,595.5	1,446.0	1,275.9	1,367.3
Shellfish						
Shrimp	1,355.6	435.5	2,298.6	1,305.2	879.0	1,512.7
Oysters	13.5	20.1	12.7	16.3	82.5	145.3
Crabs	0.6	0.5	37.3	37.4	68.3	145.6
Clams	17.0	36.1	31.1	54.6	58.9	38.6
Scallops	0.2	0.4	0.6	1.5	23.6	1.9
Abalone	1.2	7.4	4.2	7.6	12.4	7.3
Lobsters	7.2	5.8	0.2	1.7	6.9	31.0
Other	99.4	93.2	108.3	253.3	163.2	229.9
Other items[1]	46.8	18.0	16.7	37.2	40.9	133.4
Subtotal[2]	2,516.6	1,651.6	4,802.9	3,860.4	3,019.5	4,700.2
Nonedible	3.3	4.8	6.3	7.4	36.6	46.5
Grand total[2]	2,519.9	1.656.4	4,809.2	3,867.3	3,056.1	4,746.7

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

Table 7.—U.S. fishery imports from China, by value and species, 1979-84.

Category and species	U.S. imports (US$1,000) 1979	1980	1981	1982	1983	1984
Edible						
Fish						
Flatfish	23.0			18.4	274.3	284.2
Mackerel	10.4	71.6	227.8	146.4	125.4	208.7
Groundfish	44.1	95.2	99.5	132.8	92.2	307.1
Pacific cod	1.2		1.1		38.3	11.1
Pollock				54.0	34.9	337.6
Herring	4.4	2.9	0.1	17.3	0.6	0.3
Sardines	4.9	6.2	1.9	35.6		26.4
Tuna	0.4	9.3	904.4	909.5		292.6
Other	1,570.5	1,890.8	3,536.7	3,279.4	3,031.4	3,357.1
Shellfish						
Shrimp	14,904.4	3,455.8	17,718.4	11,525.4	6,055.1	12,450.8
Scallops	6.8	17.1	25.0	32.4	258.1	57.2
Oysters	115.6	87.3	63.2	78.3	252.5	318.9
Crabs	2.4	3.9	91.9	124.1	197.1	446.3
Abalone	15.7	60.5	68.2	133.5	181.3	135.7
Clams	18.5	58.8	68.6	94.5	99.3	66.4
Lobsters	27.5	40.7	1.7	15.7	73.5	261.8
Other	515.9	521.2	650.8	1,154.1	817.3	1,236.2
Other items[1]	214.1	119.3	126.7	281.2	161.7	229.8
Subtotal[2]	17,479.5	6,440.6	23,586.7	18,032.4	11,692.9	20,028.2
Nonedible	70.9	84.3	138.1	89.3	200.9	211.5
Grand total[2]	17,550.4	6,524.9	23,724.8	18,121.7	11,893.8	20,240.2

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

1983. The 1983 imports of these species totalled 246 t, worth nearly $1.0 million and double the 1982 figures of 117 t and $0.5 million, respectively.

U.S. Exports

China was the fourth largest Asian market for U.S. fishery products in 1983, after Japan, Korea, and Taiwan, and receiving direct exports of over 2,700 t, worth almost $4.1 million. However, direct U.S. fishery exports to China in 1984 were only 456 t, worth about $0.7 million.

It is not known how many U.S. fishery products reach China indirectly through re-exports, or consignment sales through third countries. U.S. fishery exports to China in 1982, 1983, and 1984 consisted almost entirely of frozen whole herring which was further processed in China (Fig. 3, 4; Tables 8, 9).

Table 8.—U.S. fishery exports to China, by quantity and commodity, 1979-84.

Commodity	1979	1981	1982	1983	1984
Edible					
Finfish					
Frozen					
Whole	1,112.0		226.2	2,691.1	455.6
Fillets				10.7	
Canned					
Cured	654.0		0.7		
Roe			2.4	2.5	
Other					
Shellfish					
Frozen					
Canned				0.5	
Other[1]					
Subtotal	1,766.1		229.2	2,704.7	455.6
Nonedible					
Fishmeal					
Fish oil		0.2			
Other					
Subtotal		0.2			
Grand total[2]	1,766.1	0.2	229.2	2,704.7	455.6

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

Table 9.—U.S. fishery exports to China, by value and commodity, 1979-84. Source: U.S. Census Bureau.

	Exports (US$1,000)				
Commodity	1979	1981	1982	1983	1984
Edible					
Finfish					
Frozen					
Whole	3,047.0		436.3	4,011.3	684.2
Fillets				30.6	
Canned					
Cured	2,162.8		18.1		
Roe			11.5	24.0	
Other					
Shellfish					
Frozen					
Canned				3.2	
Other[1]					
Subtotal	5,209.8		465.9	4.069.2	684.2
Nonedible					
Fishmeal					
Fish oil		0.5			
Other					
Subtotal		0.5			
Grand totals[2]	5,209.8	0.5	465.9	4,069.2	684.2

[1]Includes fish sticks, pastes, etc.
[2]Totals may not agree because of rounding.

New Customs Rules

China has also announced new customs regulations for various goods, including fishery products (Table 10). Effective 10 March 1985, duties were assessed according to the country of origin rather than exporting company. There are two tariff rate systems: 1) a "Minimum Tariff Rate" is applied on goods originating in countries with which China has mutually beneficial trade treaties or agreements, and 2) a "General Tariff Rate" is applied on goods from countries without special bilateral trade agreements. The reason why China is reducing the tariff rate on imports of certain fishery products and fishing vessels is because China cannot produce sufficient quantities of fish to supply its domestic demand, and because it cannot build enough high-quality fishing vessels.

It is not yet clear what China's policy changes mean for U.S. fishery exports to that nation. Some observers believe that there is a possibility that U.S. fishery exports to China, especially for inexpensive and underutilized species, such as Alaska pollock, may increase as a result of China's fishery marketing reforms. (Sources: IFR-84/104B, 85-27, and 85-28.)

Table 10.—China's customs regulations before and after 10 March 1985.

	Tariff rate (percentage)	
Product	Pre-March 10	Post-March 10
Powered ships (fishing vessels)	20	9
Freshwater and marine fish species	80	30
Abalone	150	60
Shark fins	150	60
Sea cucumbers	150	60

China Forms Joint Ventures With Japan, New Zealand

The first Japan-China fisheries joint venture, the Danyo Fisheries Company[1], was scheduled to begin operation in early 1985. The joint venture was formed between Japan's Taiyo Fisheries Ltd. and China's Danshan Fishing Company, which reportedly proposed the joint venture to Taiyo in 1983. China has supplied 55 percent of the initial capital of more than $1.2 million, while Taiyo supplied the remaining 45 percent.

The Danshan Company has purchased six fishing vessels from Japan for catching cutlassfish, drum, and sharp-toothed eel, all for export to Japan for processing. Another ten purse seiners and freezer vessels are sought. The joint venture will also be involved in shrimp farming near Shanghai and Dalian.

Yet another joint venture has been formed between Japan's Taiyo Gyogyo and a fisheries company in Chekiang Province. This new company is capitalized at ¥300 million (US$1.3 million), 55 percent from the Chinese partners. Immediate plans called for bringing trawlers from Japan to fish hairtail and croaker for sale in China. Future plans include expanded fishing operations and shrimp culture.

China also agreed to establish a shrimp farming joint venture with New Zealand, the first joint venture of any kind between the two countries. Chinese shrimp culture technicians were scheduled to visit New Zealand earlier in 1985 to study sites for shrimp farming. After a suitable site is chosen, a company will be formed which will be owned 60 percent by New Zealand interests and 40 percent by China. The two sides hope to begin commercial production to supply both New Zealand and foreign markets within 3 years. The joint venture marks the first time that China will utilize, on a commercial basis, its own shrimp farming expertise in another country.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Japan's Pacific Salmon Fisheries and Trade, 1974-84

A. George Herrfurth

Introduction

Japan obtains Pacific salmon, *Oncorhynchus* spp. (Table 1), from four sources: 1) A coastal trap-net fishery (based on returns of salmon released from hatcheries), 2) a high-seas catch, 3) imports, and 4) cage culture. This salmon supply more than doubled between 1974 and 1984 (Table 2).

An increased salmon demand, a decreased high-seas catch, and the deisre to reduce dependence on salmon imports and help domestic fishermen, prompted the Japanese Government to expand the salmon hatchery program in 1979. Hatchery returns have grown steadily since, and accounted for 45 percent of Japan's salmon supply in 1983, according to the Japan Fisheries Agency (JFA).

Japan's annual salmon imports averaged 10,000 metric tons (t) in the middle 1970's, owing to lower demand and no 200-mile fishing zone restrictions. Since then, however, the United States has become Japan's leading salmon supplier and exports to Japan increased markedly during the past decade because of Japan's growing salmon demand and decreasing high-seas catches. Japanese imports of U.S. salmon were over 96,000 t in 1983, but were expected to be lower in 1984 because of an over-supply of salmon in Japan.

Japan's hatchery programs, however, cannot completely replace imports. Chum salmon, *Oncorhynchus keta*, is the primary species in the Japanese hatchery program, while most imported salmon is sockeye, *O. nerka*. The coho salmon, *O. kisutch*, is the primary cage-cultured species.

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Table 1.—Names of the Pacific salmon.

English name	Japanese name	Scientific name
Cherry salmon	masu	*Oncorhynchus masou*
Chinook salmon[1]	masunosuke	*O. tshawytscha*
Chum salmon	sake	*O. keta*
Coho salmon[2]	gin-zake	*O. kisutch*
Pink salmon	karafuto-masu	*O. gorbuscha*
Redspot salmon	amenouo	*O. rhodurus*
Sockeye salmon[3]	beni-zake	*O. nerka*

[1]Also called king salmon.
[2]Also called silver salmon
[3]Also called red salmon; the land-locked form is called kokanee salmon.

Table 2.—Japan's salmon supply, 1974-84[1].

Year	Catch (1,000 t) Coastal[2]	High-seas[3]	Culture	Total	Trade (1,000 t) Imports	Exports	Balance	Total supply (1,000 t)
1974	39.2	86.9		126.1	8.3	13.1	+ 4.8	121.3
1975	64.2	91.0		155.2	10.7	19.9	+ 9.2	146.0
1976	38.1	82.2		120.3	9.5	20.8	+ 11.3	109.0
1977	45.5	62.6		108.1	26.4	4.7	− 21.7	129.8
1978	59.1	41.5	0.1	100.7	57.9	4.2	− 53.7	154.4
1979	87.3	42.4	0.4	130.1	64.7	1.7	− 63.0	193.1
1980	79.9	42.5	1.9	124.3	48.7	1.3	− 47.4	171.7
1981	107.9	42.5	1.2	151.7	83.1	1.7	− 81.4	233.1
1982	101.5	42.4	2.1	146.0	117.7	0.5	−117.2	263.2
1983	120.6	42.5	2.9	166.0	108.5	0.9	−107.6	273.6
1984	N/A[4]	40.0	4.5E[5]	N/A	N/A	N/A	N/A	N/A

[1]Catch is given in live weight and trade statistics are in product weight. Since over 90 percent of all salmon imported in recent years was whole fresh or frozen, the total supply weight has only a small margin of error.
[2]The Japanese refer to this catch as the "hatchery returns" catch. In addition to the inshore coastal catch, the figures also include the inland salmon catch, but exclude a small cherry salmon and landlocked salmon catch.
[3]The Soviet-granted catch quota was 42,500 t from 1978 to 1983; in 1984, it was reduced to 40,000 t.
[4]N/A = Not available.
[5]E = Estimate.

Table 3.—Japan's salmon catch, by species, 1974-83.

Species	Catch (t) 1974	1975	1976	1977	1978	1979	1980	1981	1982	1983[1]
Chum	80,146	99,485	78,417	71,931	74,089	101,466	96,920	120,801	111,760	
Pink	32,537	45,936	29,629	35,264	17,176	24,060	20,101	25,509	20,797	
Coho	9,713	8,161	7,697	3,757	5,755	2,708	3,634	3,285	5,022	
Sockeye	8,155	7,733	8,844	4,601	5,261	5,510	6,070	5,227	4,269	
Cherry	3,101	3,871	3,814	3,822	3,600	2,669	2,777	3,296	3,681	
Chinook	1,867	1,115	1,604	908	1,075	1,227	2,484	1,381	1,018	
Total[2]	135,519	166,301	130,005	120,283	106,956	137,640	131,986	159,499	146,527	166,000

[1]Preliminary estimate.
[2]FAO and Japanese catch statistics do not always agree (see "Total catch" in Table 2).

The Fisheries

Japan catches salmon in both coastal and high-seas fisheries and farms them in coastal cages. Until the middle 1970's, most of Japan's catch was taken by the high-seas fleet. However, the Soviet declaration of a 200-mile fishing zone in 1976, and subsequent insistence that the Japanese reduce their high-seas catch of Soviet-origin salmon, sent Japan's high-seas catch to a low of 107,000 t in 1978.

The Government enlarged its hatchery program in 1979 to improve coastal harvests, and the program has been remarkably successful. Thus, the increasing coastal catch helped Japanese fishermen land a record 166,000 t of salmon in 1983. Several species of Pacific salmon are caught by Japanese fishermen, but most (>75 percent in 1983) are chum salmon (Table 3).

Coastal

Japan's coastal salmon fishery is conducted almost entirely with fixed gear. Trap nets are set in shallow coastal waters near the natal rivers where the hatchery-produced salmon return to

Table 4.—Salmon hatchery programs in Hokkaido and Honshu, 1974-87.

Year	Fry released (in millions)			Salmon returns[1] (1,000 t)		
	Hokkaido	Honshu	Total[2]	Hokkaido	Honshu	Total[2]
1974	485	272	757	35.1 (2.2)	4.0 (0.8)	39.2 (1.8)
1975	802	344	1,146	57.6 (2.7)	6.7 (0.9)	64.2 (2.2)
1976	523	287	810	32.1 (1.9)	6.0 (0.7)	38.1 (1.5)
1977	693	413	1,106	37.3 (2.3)	8.2 (0.8)	45.5 (1.7)
1978	779	433	1,212	48.0 (2.7)	11.2 (1.1)	59.2 (2.1)
1979	873	590	1,463	69.0 (2.4)	18.7 (1.5)	87.7 (2.1)
1980	1,146	750	1,896	56.4 (3.0)	25.4 (2.4)	81.8 (2.8)
1981	1,080	738	1,818	80.0 (3.2)	29.1 (1.9)	109.1 (2.7)
1982	1,108	864	1,972	73.1 (2.6)	30.4 (1.9)	103.6 (2.3)
1983	1,147	829	1,976	84.0 (2.6)	39.5 (1.8)	123.5 (2.3)
1984	1,179[3]	846[3]	2,025[3]	N/A[4]	N/A	N/A
1985	N/A	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	N/A	100.7 (2.5)E[5]	40.2 (1.9)E	140.9 (2.3)E

[1]Includes cage-culture production. Data in parentheses indicate percentage rates of return of salmon fry released 4 years earlier.
[2]Totals may not agree because of rounding.
[3]Releases planned for 1984.
[4]N/A = Not available.
[5]E = Estimated from salmon fry released in 1984.

Table 5.—JFA budget for the Salmon Culture Program, 1979-84.

Item	Budget (millions of yen)					
	1979	1980	1981	1982	1983	1984
Cost of governmental hatcheries	¥2,005	¥2,200	¥2,264	¥2,186	¥2,218	¥2,070
Subsidies to private hatcheries[1]	1,241	1,386	1,409	1,289	1,241	1,172
Total (millions of yen)	¥3,246	¥3,586	¥3,673	¥3,475	¥3,459	¥3,242
Total (millions of U.S. dollars)	$14.7	$15.9	$18.6	$13.9	$14.5	$14.1

[1]The 1951 "Aquatic Resources Conservation Law," obligates the Japanese Government to subsidize the expenses of privately managed salmon hatcheries, provided that coastal fishermen also bear part of the expenses.

spawn after being at sea 3-7 years.

The coastal fishery is also entirely dependent on the returns of hatchery-raised chum salmon. Those which escape this commercial fishery, and continue their migration upriver, are collected in weirs for delivery to hatcheries where they are spawned to complete the life cycle.

Japan's salmon hatchery programs have been exceptionally successful, and returns have increased steadily. The coastal catch of hatchery-produced salmon increased from 39,200 t in 1974 to 120,600 t in 1983, or by 200 percent (Table 2). The increased returns were especially pronounced during the early 1980's and were the result of the 5-year (1979-83) salmon culture program sponsored by the Japanese Government.

This program was carried out by 44 governmental and about 220 private hatcheries in Hokkaido and Honshu, and increased releases and new release methods reportedly insured the program's success. Although the salmon return 3-5 years after release, the JFA calculates the returns for an average 4-year period (Table 4).

Japan released nearly 2 billion salmon fry in 1983 (1.2 billion from government hatcheries and 0.8 billion from private hatcheries). Most (1.8 billion—94 percent) were chum fry. The Japanese also released small amounts of sockeye; pink, *O. gorbuscha*; cherry, *O. masou*; and kokanee, *O. nerka*, salmon fry in 1983. Japanese coastal fishermen expect to harvest 140,900 t, or about 38.6 million mature salmon in 1987.

The JFA has expressed concern about a new 5-year salmon hatchery program (1984-88) because of the long-term effect it might have on prices and the costs involved. If the 1987 projected hatchery returns are accurate and if salmon imports continue to increase, JFA officials believe that salmon supplies might exceed the demand, resulting in lower prices. The JFA is therefore considering a hatchery enhancement program for fry of such high-valued species as cherry and sockeye salmon (i.e., qualitative rather than quantitative hatchery enhancement). The JFA is also considering sponsoring new efforts to advance the return season of chum salmon to increase its oil content and value since the Japanese prefer a "fatty" salmon.

Financial problems are also affecting plans for a new 5-year salmon hatchery program. The Japanese Finance Ministry does not wish the JFA to continue assuming the large burden of financing the hatchery program and believes that coastal trap-net fishermen should contribute more to the hatchery program since they benefit most from the salmon returns. In 1983, Japanese fishermen paid only $5.5 million of the $20.0 million spent on the hatchery enhancement program, while the JFA salmon culture budget supplied the remaining $14.5 million (Table 5).

High-Seas

Japan's high-seas salmon fishery consists of mothership, drift-net, and longlining operations in the North Pacific. Japan also depends on annual catch quotas granted by the U.S.S.R. for its high-seas salmon catch, about 90 percent of which was spawned in Soviet rivers[1].

Until 1977, Japan obtained most of its salmon from the high-seas (65 percent in 1974). By 1983, however, only 16 percent came from this fishery (Fig. 1), as the Soviet quotas were reduced more than 52 percent (from 83,000 t in 1974 to 40,000 t in 1984).

The most significant quota reduction occurred in 1978 when the U.S.S.R. proposed a total ban on the Japanese high-seas salmon fishing and, as a compromise, reduced Japan's salmon quota from 62,000 t to 42,500 t, where it remained through 1983. During the 1984 negotiations, the Japanese high-seas salmon quota was further reduced to 40,000 t.

The bilateral salmon agreement also requires Japan to pay fishery fees. These are paid in goods related to the enhancement of the Soviet Pacific salmon industry. Although Japan's annual high-seas salmon quota was constant between 1978 and 1983, Soviet fishing fee demands increased. In 1978 Japan paid Russia $8.5 million ($200/t), and in 1983 the fees had more than doubled to $17.9 million

[1]In addition to the U.S.S.R. salmon quota, established by a bilateral agreement, Japanese fishermen also operate under the terms of the International North Pacific Fisheries Convention (INPFC).

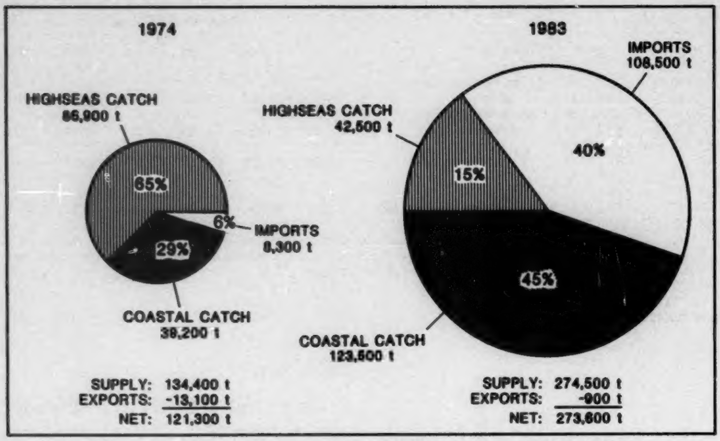

Figure 1.—Japan's salmon supply, excluding exports, 1974 and 1983.

Table 6.—The seven Japanese chum salmon gradings, after W. C. Atkinson (1984), "The Japan Salmon Market with Emphasis on the Market for Kotzebue Chum Salmon").

Grading	Description
Mejika	"Ocean bright" salmon taken in the high-seas catch; mean is firm, skin color is healthy.
Ginke	"Silver bright" salmon taken in the coastal catch; meat is firm, skin color is healthy.
Buna "A"	"Dark salmon" taken in the coastal catch; color of skin and flesh is slightly changed.
Buna "B"	"Dark salmon" taken in the coastal catch; skin and flesh colors have darkened.
Buna "C"	"Dark salmon" taken in the coastal catch. This is the darkest colored chum in the coastal catch.
River Buna	"River dark" salmon taken in rivers (inland catch); these are salmon taken just prior to spawning.
Marked	Damaged or wounded chum salmon.

($421/t). The Japanese Finance Ministry has criticized this fee because the Japanese fishing industry pays only 55 percent of it, while the remaining 45 percent is subsidized through the JFA budget.

Cage Culture

Japanese fish farmers raise only the coho or silver salmon in ocean cages. Salmon farming began in 1973 when 1 million coho eggs were imported from the United States for experimental freshwater culture. Japanese pen-farming operations switched to ocean-cage farming in 1975 because the salmon had a slow growth rate in fresh water.

Japan's coho production increased from 72 t in 1978 to 2,900 t in 1983 (Table 2) and all was consumed domestically. Japanese companies expected to harvest 4,500 t of farmed salmon in 1984 and as much as 8,000 t by 1990. More than half of the 1984 harvest will be produced by the Nichiro company (2,500 t), followed by Taiyo (1,000 t), Nichimo (500 t), and various smaller companies (500 t). The Japanese Government does not offer financial incentives to salmon farmers as they do to private salmon hatchery operations, and apparently prefers to "let the market decide."

Domestic Markets

Salmon is popular in the Japanese diet, especially as a holiday gift item. Consumption was minimal before 1960, however, and limited mainly to northern Japan where the fish were caught. Since then, salmon consumption has increased throughout Japan owing to population growth, extensive advertising, fluctuating supplies of other fishery products, and an increase in per capita income. Observers forecast that the Japanese salmon consumption will expand if prices do not increase significantly.

Japan's salmon market was over-supplied in 1983 by record coastal catches and large imports. This depressed salmon prices and, in some instances, resulted in their dumping. Although the JFA projected that the fall 1984 coastal catch would be lower than in 1983, observers believed that 1984 salmon imports would also decline.

Commodities

Most salmon in Japan is salted, smoked, or canned; the rest is consumed fresh. Although per capita consumption of salted and smoked salmon has increased greatly in recent years, fresh salmon consumption has increased only marginally, perhaps because the Japanese traditionally favor salted and smoked salmon over fresh salmon.

Salmon roe, a favored delicacy in Japan, is mostly cured, either as "sujiko" (in the membranous skein) or "ikura" (eggs separated from the skein). It is especially consumed during the New Year holidays (Oshogatsu).

Species

Chum salmon is the cheapest and most abundant salmon in Japan, and more of it is consumed there than any other salmon. Mostly salted or smoked, it is obtained from the coastal catch; only small quantities are processed from imports or the high-seas catch.

When landed, chums are systematically graded by age and condition. Those with bright skin, firm and "good color" flesh, and high fat content are rated highest, while old and spent or damaged salmon are rated among the lowest of the seven gradings (Table 6).

Chum salmon have long been popular gifts in Japan. However, Japanese wholesalers see a need to reassess the so-called "gift salmon" market since the 1983 record-high chum landings depressed market prices. Lower prices resulted in decreased demand as many Japanese consumers saw the low-priced and abundant product as an undesirable gift item. One Japanese wholesaler believes that Japanese consumers may switch from chum to sockeye as a gift item if there is an over-supply of chum in the future, since sockeye is not only more expensive, but is also thought to be a better tasting, fattier salmon with redder flesh.

Sockeye and pink salmon are also popular in Japan. Sockeye is the species

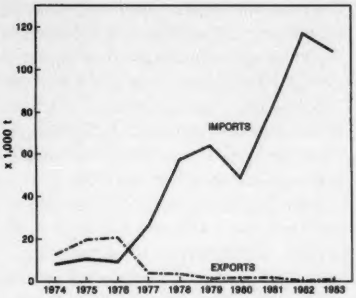

Figure 2.—Japan's salmon imports and exports (product weight), 1974-83.

Table 7.—Japan's salmon imports by commodity and country, 1977-84.

Commodity and country	Imports (t)							
	1977	1978	1979	1980	1981	1982	1983	1984
Fresh								
United States	50	27	74	6	38	206	1,272	5
Norway				2	29	33	78	179
Other countries	5	15	6	6	428	6	7	69
Subtotal	55	42	80	14	495	245	1,357	253
Frozen								
United States	14,834	40,833	48,030	33,019	60,212	93,063	86,669	80,271
Canada	3,706	7,053	4,720	2,641	5,157	10,834	3,837	5,178
Taiwan	31	5					3,687	2,413
North Korea	662	1,808	1,382	1,674	3,002	1,501	1,188	1,661
South Korea	12	7	25	6	359	1,362	1,928	1,982
U.S.S.R.			439	1,991	2,546	645	254	1,363
Other countries	34	32	15	1	65	73	283	110
Subtotal	19,279	49,738	54,618	39,331	71,341	107,478	97,848	92,978
Cured								
United States							7	695
Canada							121	563
North Korea							17	10
Subtotal							145	1,268
Roe								
Cured[1] (sujiko)								
United States	5,554	6,319	6,799	7,403	9,509	8,596	8,098	8,544
Canada	1,110	1,474	983	1,154	1,190	982	648	629
Other countries	18	10	9	43	33	59	36	33
Subtotal	6,682	7,803	7,791	8,600	10,732	9,637	8,782	9,206
Cured[1] (ikura)								
United States	80	35	50	50	10	2	77	19
Canada	4	2	9	negl.	2	negl.	4	2
China	32	17	8	3				
Other countries	5	7	9	1	1	negl.	1	5
Subtotal	121	61	76	54	13	2	82	26
Canned								
United States	214	213	1,547	345	294	121	93	20
U.S.S.R.	60	1	390	415	203	112	117	137
Canada	1	60	232	29	61	87	65	41
Other countries	negl.	negl.	1	1	3	1	2	4
Subtotal	275	274	2,170	790	561	321	277	[2]202
Grand total[3]	26,412	57,918	64,736	48,789	83,142	117,685	108,491	103,933

[1]"Sujiko" is cured roe in the skein. "Ikura" is cured roe separated from the skein.
[2]Japan's canned salmon imports were only available from January through November 1984.
[3]Totals may not agree because of rounding.

most imported, while the pink accounts for Japan's second-largest salmon catch. Both species are favored by Japanese buyers who prefer that fish be landed or imported in the "princess cut" style (head-on) so quality-conscious consumers can better evaluate it for eye clarity and proper handling.

Trade

Before 1977, Japan exported more salmon than it imported. Since then, however, increasing demand (especially for species less harvested by Japanese fishermen), combined with declining high-seas catches, have greatly increased salmon imports (Fig. 2, Table 2), i.e. 108,500 t were imported vs. 900 t exported in 1983.

Imports

Japan's salmon imports (primarily frozen) increased from 8,300 t in 1974 to 108,500 t in 1983, largely owing to the high-seas catch decline, growth in salmon demand by increasingly affluent consumers, and fluctuating exchange rates. For example, 1978 salmon imports more than doubled from 1977 because a strong yen made U.S. salmon purchases less expensive. Also, Japanese importers were concerned about future salmon supplies which seemed uncertain after the Soviet Union reduced Japan's salmon catch quota 32 percent (20,100 t).

As a result of the increased imports, Japan accumulated large inventories of frozen salmon in 1979, which overlapped into 1980, causing a 30 percent decrease in salmon imports. Then, during 1981 and 1982, salmon imports increased nearly 130 percent (from 48,700 t to 117,700 t) as domestic demand increased.

In 1983, Japan's salmon imports again decreased (to 108,500 t) as a result of the record domestic catch. This 1983 "glut" also depressed Japan's salmon prices 30-40 percent in the wholesale market, and by 20 percent in the retail market. Preliminary FAO estimates[2] forecast that Japan's 1984 imports of frozen salmon would be 70,000-75,000 t, a 30 percent drop from 1983 imports, which would adversely impact many U.S. salmon exporters.

Japan imports more salmon from the United States than from any other country (Table 7). Their 1983 imports totaled over 96,000 t, and accounted for 90 percent of Japan's total salmon imports by quantity. Frozen salmon was the largest commodity imported (86,700 t), followed by salmon roe (8,175 t), fresh salmon (1,272 t), and canned salmon (93 t).

The United States was the largest sup-

[2]FAO, "Infofish Trade News" (84/11), 16 June 1984.

Table 8.—Japanese imports of salmon products from the United States, by species, 1977-84.

Species	Imports (t)							
	1977	1978	1979	1980	1981	1982	1983	1984
Sockeye	N/A[1]	N/A	N/A	N/A	42,387	55,226	71,664	56,468
Chum	N/A	N/A	N/A	N/A	6,564	8,251	6,069	6,261
Chinook	N/A	N/A	N/A	N/A	2,548	1,432	2,465	1,172
Pink	N/A	N/A	N/A	N/A	1,061	12,876	1,556	10,167
Other[2]	N/A	N/A	N/A	N/A	16,303	22,503	12,729	11,920
Total[3]	15,594	41,418	44,596	30,914	68,863	100,268	94,483	85,988

[1]N/A = Not available.
[2]Unidentified salmon species; includes canned and filleted products and salmon roe.
[3]U.S. and Japanese trade statistics do not agree (i.e., 1983 U.S. Department of Commerce trade statistics indicate that the U.S. exported 94,483 t of salmon to Japan; Japanese trade statistics, however, showed U.S. exports of 96,217 t).

plier of fresh salmon to Japan in 1983, accounting for 1,272 t, or 93.8 percent of the total (Table 7). Norway was the second largest supplier (but of Atlantic salmon, *Salmo salar*), providing 77.5 t, or 5.7 percent of the total. Preliminary Japanese trade statistics through May 1984 indicated that Norway had already exported almost 94 t of fresh Atlantic salmon to Japan, 20 percent more than in 1983. Observers believe that Norway's farmed Atlantic salmon exports to Japan will continue to compete with U.S. fresh Pacific salmon exports.

Sockeye or red salmon has been the leading U.S. species imported by Japan in recent years (Table 8). In 1983, the sockeye accounted for over 75 percent by quantity and 70 percent by value of U.S. salmon shipments to Japan.

U.S. salmon exporters were not greatly affected by Japan's record salmon hatchery returns in 1983. U.S. shipments totaled over 96,000 t in 1983, a decline of only 5 percent from the nearly 102,000 t exported in 1982 (Table 7). This is because Japan released and harvested mostly chum salmon and not sockeye salmon—the primary U.S. export species.

Concern among U.S. salmon exporters may develop, however, if Japan expands hatchery efforts on sockeye salmon. In 1983, the JFA released 61,000 sockeye fry, and observers reported that the JFA planned to hatch and release 100,000 sockeye fry by 1985. If the sockeye returns are successful, the JFA may increase such releases in the future.

Exports

Japan enjoyed a favorable balance of trade in salmon products until 1976 (Table 2). However, salmon product exports have since declined (Fig. 2), especially in 1977 after the Soviets decreased Japan's high-seas catch quota. Expanded domestic salmon demand in recent years also contributed to the export reduction.

Both in 1982 and 1983, Japan exported less than 1,000 t of salmon products. However, Japanese trade statistics through May 1984 indicated that Japan's early 1984 salmon exports (1,000 t) had already exceeded 1983 exports, which observers indicate was due to the 1983 over-supply of salmon on the Japanese market.

Conclusions

The factors which continue to influence Japan's salmon supply include: 1) Coastal (hatchery-produced) chum catches, 2) salmon imports, and 3) high-seas catches. Japan must carefully balance these factors to meet the domestic demand while not over-supplying the market (as in 1983).

The high-seas catch represents an especially difficult problem since it depends on annual bilateral quota agreements with the Soviet Union. Japan has tried to convince Soviets to agree to a long-term salmon agreement that would assure economic stability for Japanese high-seas salmon fishermen and also assure domestic markets a specified portion of the total salmon supply for several years. So far the Soviets have been unwilling to agree to this proposal.

Japan will remain the largest foreign market for U.S. salmon exports. The amount of U.S. exports will depend, however, upon Japan's domestic demand for salmon. Some observers believe that Japanese consumers are developing a greater affinity for U.S. sockeye over the traditionally favored chum. Salmon prices will also influence U.S. exports, since the typical Japanese consumer is price-conscious about seafood.

Japan's salmon catches (both coastal and high-seas) will also influence U.S. exports. Furthermore, if Japan's high-seas salmon quota is reduced in the future, U.S. salmon exports would probably increase. (Source: IFR-84/79B.)

Status of Mexico's Fisheries, 1983-84

Mexico's Fisheries Secretary Pedro Ojeda Paullada has announced that the Mexican Government's goal is to more than double the 1983-84 fisheries catch of 1.1 million metric tons (t) (data adjusted for the period 1 Sept.-31 Aug.) to 2.5 million t by 1988. While the 1983-84 harvest was less than in previous years (Table 1), the apparent decline probably reflects more accurate statistical reporting and the lingering results of the of the 1982-83 El Niño on the important Pacific Coast small pelagic fisheries . Secretary Ojeda's remarks came in a late 1984 briefing of the Mexican Congress on the status of the fisheries.

Mexico has a mixed economy and the three major economic sectors (private, cooperative, and public) each play an important role in the fishing industry. The private sector takes the largest quantity of fish, about 66 percent during 1983-84. Most of the private catch

Table 1.—Mexico's fish catch, recent and projected (1988).

Year[1]	Catch (1,000 t)
1975	467.5
1976	526.3
1977	610.8
1978	702.6
1979	877.0
1980	1,243.6
1981	1,564.8
1982	1,506.0
1983-84[2]	1,100.0
1988	2,500.0

[1]Calendar year.
[2]Sept.-31 Aug.

is small pelagic species which are reduced to fishmeal and oil. The cooperative sector only takes 25 percent of the country's fisheries catch, but because that includes shrimp, lobster, abalone, and other valuable species, the cooperatives account for the largest share of the catch value. The publicly owned state companies only account for about 9 percent of the catch in terms of quantity, but almost all is of edible species, and as a result state companies play an important role in supplying foodfish to the domestic market. The Secretariat of Fisheries (SEPESCA) hopes to more than double the catch of the state corporations by 1988. The state companies also play a critical role by helping the cooperatives export their shrimp catch to the United States and other foreign markets.

The state companies, Productos Pesqueros Mexicanos (PPM) and Industrias Pesqueras Paraestatales del Noroeste (IPPN) play a more important role in processing the country's catch. Mexico has 421 processing plants. Most are operated by private companies which, combined, process about 57 percent of Mexico's catch. Even so, the state companies operate the largest and most modern plants, processing about 42 percent of the total catch, but a much larger portion of edible species. The proportion of the catch processd by the state companies should increase sharply when PPM has its large new plants at Lerma (Campeche) and Topolobampo (Sonora) operating at full capacity. Cooperative plants only account for about 1 percent of production, processing almost entirely shellfish. In recent years, SEPESCA has experimented with joint ventures, allowing both private investors and cooperatives to participate in some of the PPM and IPPN projects.

The Secretary commented on the record 90,000 t 1983-84 shrimp catch, which he said demonstrated the validity of the Government's cooperative policy. Some observers, however, believe that climatic conditions may have been even more important. He also stressed that the country's fisheries catch would have been much higher had not the El Niño event affected Pacific Coast small pelagic fisheries.

The Secretary gave special attention to freshwater fisheries and aquaculture. The 1983-84 aquaculture and freshwater fisheries catch totaled 122,000 t, mostly tilapia, carp, catfish, trout, oyster, and freshwater shrimp. SEPESCA hopes to triple production to nearly 390,000 t by 1988. Mexico currently has 33 aquaculture centers and 4 hatcheries producing fry and postlarval shellfish.

Secretary Ojeda also reviewed many of the special initiatives of the current Administration, discussing administrative decentralization, intersectorial coordination, scientific investigation, training, finances, and simplifying government regulations. (Source: IFR-84/95.)

The U.S. Regional Fisheries Attache in Mexico City has also prepared a 9-page report on the Mexican fishing industry, including statistical appendices and a list of fishery cooperatives. The report can be purchased for $13.00 by ordering report PB85-114189 from NTIS, 5285 Port Royal Road, Springfield, VA 22161.

Japan and China to Produce Clams

Plans were announced earlier this year for two Japanese companies to process short-necked clams in China and import the market-ready products and sell them under an agreement of compensatory trade later in 1985. The clams were to be produced at a freezer factory in Lianoning Province in northeastern China, with the two Japanese companies furnishing processing equipment and necessary materials and technology for the vacuum sealing and heat sterilization methods. The clams were to be packed in 300 g packages and initial production was expected to be over 50 t per month.

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

Mexican Shrimping Costs, 1985

The U.S. Regional Fisheries Attache (RFA) in Mexico City, Charles Finan, has obtained a report from the Mexican Federation of Fishery Cooperatives assessing the costs of shrimp fishing in Mexico (Table 1). The costs are based on the operation of a 75-foot steel-hulled shrimp trawler, and the report is the most complete and up to date study available on the cost of shrimp fishing in Mexico. It is estimated that it costs about US$9.80 to produce and process 1 kg of shrimp, but that does not include the cost of the vessel or interest charges. These costs appear to be quite high, but include all payment to cooperative members. (Source: IFR-85/34)

Table 1.—Cost analysis[1,2,3] of a Mexican shrimp trawler (1 trip).

Item	Cost in pesos (P)
Fixed costs	
Diesel Fuel (30,000 L)	P984,000
Lubricant (2 Barrels)	105,120
Food	140,000
Deck equipment	50,000
Spare parts	50,000
Freon, salt, ice	75,000
Repairs	
Fishing gear	50,000
Electrical equipment	45,000
Other equipment	110,000
Subtotal	P1,609,120
Variable costs	
Freezing and packing	187,500
Taxes (SPT-0.023)	71,875
Export duty (1 percent)	31,250
Commission to distributor (7.5 percent)	234,375
Transit and port charges	137,500
Prepayment to members	585,930
Administration	173,437
Social Security	50,000
Social quotas	50,000
Subtotal	P1,503,117
Total cost/trip	P3,112,237

[1]As of 28 May 1985, the Mexican peso traded for P254 (floating rate) to the U.S. dollar.
[2]Value of 1 kg of shrimp = P2,500.
[3]Value of an average shrimp catch of 1,250 kg = P3,125,000.

New NMFS Scientific Reports Published

Some publications listed below may be sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Copies of all are sold by the National Technical Information Service, Springfield, VA 22151. Writing to either agency prior to ordering is advisable to determine availability and price (prices may change and prepayment is required).

NOAA Technical Report NMFS 20. Kendall, Arthur W., Jr., and Jean R. Dunn. **"Ichthyoplankton of the continental shelf near Kodiak Island, Alaska."** January 1985, iii + 89 p., 5 figs., 7 tables, 87 app. figs.

ABSTRACT

Eleven ichthyoplankton surveys were conducted (1 in 1972 and 10 between 1977 and 1979) in the northeastern Pacific Ocean over the continental shelf off Kodiak Island, Alaska. In the 677 neuston and 632 bongo tows, eggs or larvae of more than 80 fish taxa were found. They were present in every season and throughout the survey area, although more taxa and more individuals were found in summer than in other seasons. Among the more abundant species were the gadid *Theragra chalcogramma* and several hexagrammids and pleuronectids. The hexagrammids and several cottids were abundant in the neustonic layer, where they spent close to a year as larvae and prejuveniles. Although the seasonal and geographic distribution of most taxa was complex, two patterns emerged: Late summer-fall spawners produce demersal eggs and have neustonic larvae that remain pelagic for several months (hexagrammids and some cottids), and spring-summer spawners have pelagic eggs and larvae that spend several weeks in the plankton but are not closely associated with the surface (*Theragra chalcogramma*, pleuronectids).

NOAA Technical Report NMFS 21. Renaud, Maurice L. **"Annotated bibliography on hypoxia and its effects on marine life, with emphasis on the Gulf of Mexico."** February 1985, iii + 9 p.

ABSTRACT

This bibliography contains 73 annotated references from publications and reports concerning hypoxia, ≤2.0 ppm dissolved oxygen concentration, in the Gulf of Mexico. Instances of hypoxia from similar habitats and the effects of low oxygen levels on marine or estuarine organisms are also included.

NOAA Technical Report NMFS 22. Raju, Solomon N. **"Congrid eels of the**

Game Fish Records of the World

The heart of the International Game Fish Association's annual series entitled **"World Record Game Fishes"** will probably always be its records listings, and the 1985 edition is no exception. The 65-page Section 4 details for trophy anglers the freshwater and saltwater all-tackle, line class, and fly fishing world records as granted by the International Game Fish Association as of 1 January 1985, and the list of winners in the Ninth Annual IGFA's Fishing Contest (the most entries, interestingly, were for the pink salmon, *Oncorhynchus gorbuscha*); the Tenth Contest is currently underway and certificates are awarded for the three heaviest catches of each species.

But many sportsmen and conservation leaders will find the articles in Section 2 of equal or greater interest. This year it includes a large section of Great Lakes fishing by such outdoor writers as Fred David (Lake Ontario), Maggie Kelch (Lake Erie), Ken Darwin (Lake Michigan), John Power (Lake Huron), and Butch Furtman (Lake Superior). Al Ristori has contributed an in-depth article "The Canyon Revolution," on angling for big game fishes along the U.S. East Coast's continental shelf edge along the middle Atlantic, from Norfolk Canyon to Block and Atlantis Canyons.

IGFA has also reprinted the excellent *Field and Stream* article on the bull and Dolly Varden trouts by A. J. McClane. In another piece, Olaf R. Braekkan, Director of Fisheries at the Institute of Nutrition, Bergen, Norway, provides a concise description of "The Nutritional Value of Fish." And NMFS Director William G. Gordon has contributed a thorough review of "The Why and How of Fisheries Management," outlining for sportsmen the reasons for and needs of game fish management and conservation. Another important article, "History of IGFA," relates the role of sportsmen in establishing the organization and IGFA's role in promoting gamefish conservation and management and angling ethics worldwide. It is well illustrated with historical photographs from IGFA's extensive files.

In addition, Section 5 provides illustrations, charts, and pertinent data to aid anglers in identifying over 150 fresh- and saltwater game fishes, plus a glossary of scientific and descriptive terms, and a multilingual guide to the common names of nearly 70 saltwater game fishes in English, French, German, Hawaiian, Italian, Portuguese, Japanese, and Spanish.

Section 1 provides pertinent data on the IGFA itself and its many programs while several Appendices list U.S. and world angling records-keeping organizations or agencies and worldwide tagging programs. Other useful data include an illustrated guide to fishing knots, charts of water temperature ranges for fresh and saltwater fishes, and a conversion table for weights and measures. In sum, this is an excellent and most useful compendium of data and information for sportsmen and others involved in game fish conservation and angling. The paperbound 304-page volume is sold by the IGFA, 3000 E. Las Olas Blvd., Fort Lauderdale, FL 33316-1616 for $9.75 postpaid in the United States ($11.95 to foreign addresses); it is also provided to

eastern Pacific and key to their leptocephali." February 1985, iii + 19 p., 12 figs., 2 tables.

ABSTRACT

This study indicates that 13 species of congrid larvae belonging to 8 genera occur in the eastern Pacific. The species are: *Ariosoma gilberti*; *Paraconger californiensis*; *Paraconger* sp.; *P. dentatus*; *Chiloconger labiatus*; *Taenioconger digueti*; *T. canabus*; *Gorgasia punctata*; *G. obtusa*; *Gnathophis catalinensis*; *Hildebrandia nitens*; *Bathycongrus macrurus*; and *B. varidens*. The morphological and anatomical changes undergone during metamorphosis are useful in the identification of the larvae. Larvae are distributed closer to the coastal waters, and are more common from January to May than from June to December. A key to the larvae was developed based on the myotomal counts, adult vertebral counts, pigmentation patterns, and the nature of the teeth and tail tip to distinguish the genera and species. This study shows that Garman's unidentified larvae, *Atopichthys acus* and *A. cingulus*, are two different larval stages of *Ariosoma gilberti*, and points out that *Atopichthys dentatus* and *A. obtusus* belong to *Paraconger* and *Gorgasia*, respectively.

NOAA Technical Report NMFS 23. Darcy, George H. **"Synopsis of biological data on the pinfish, *Lagodon rhomboides* (Pisces: Sparidae)."** February 1985, iv + 32 p., 22 figs., 24 tables.

ABSTRACT

Information of the biology and resources of the pinfish, *Lagodon rhomboides* (Pisces: Sparidae), is compiled, reviewed, and analyzed in the FAO species synopsis style.

NOAA Technical Report NMFS 24. Cook, Steven K. **"Temperature conditions in the cold pool 1977-81: A comparison between Southern New England and New York transects."** February 1985, iii +22 p., 5 figs., 5 tables, 14 app. figs.

ABSTRACT

Expendable bathythermograph data collected by the Ships of Opportunity (SOOP) - Ocean Monitoring Program are analyzed for seasonal and inter-annual variations of the cold pool. Two major SOOP transects within the Middle Atlantic Bight (Southern New England and New York) have been analyzed for the years common to both (1977-81). During the years 1977-81, over 200 transects were occurpied, and almost 3,000 XBT's were dropped.

Results show that the cold pool is formed with the onset of spring warming and persists until fall overturn, is consistent year to year in both area and weighted average annual temperature, and advects water from the northeast to the southwest. Results also show a 100-d lag in minimum temperature between the Southern New England and New York transects. Differences in bathymetry between the two transects and their influence on the cold pool are also discussed. Plots of average (1977-81) bottom temperature for both transects are discussed and show consistent annual weighted mean temperature and areas. Bottom temperature plots for individual years, as well as maximum and minimum bottom temperature plots, are presented as Appendix figures.

NOAA Technical Report NMFS 25. Hargis, William J., Jr. (editor). **"Parasitology and pathology of marine organisms of the World Ocean."** March 1985, iv + 135 p. (37 papers.)

IGFA members as part of their $20 membership fee.

Developing U.S. Marine Recreational Fisheries

"Marine Recreational Fisheries 9," published for the International Game Fish Association, National Coalition for Marine Conservation, and the Sport Fishing Institute by the NCMC, is devoted entirely to the discussions of the many facets of marine recreational fisheries development at the Ninth Annual Marine Recrational Fisheries Symposium. And, like previous symposia and resulting publications, this one is divided into several panels.

In Panel 1, an introduction to fisheries development chaired by Robert G. Hayes, Richard B. Thompson of the NMFS Northwest Regional Office reported the latest data on marine anglers, angling, and harvests. John T. Everett, Chief, NMFS Policy and Planning Staff, discussed fisheries development in relation to marine recreational fishing, while Eugene S. Fritz and Francis M. Schuler, with the National Sea Grant College Program addressed the question "Why develop MRF?"

In Panel 2, the marine recreational fishing industry chaired by Carl R. Sullivan, angler and guide Ron Young provided a sportsman's view of some of the problems and needs of MRF while William P. DuBose, IV, and Gilbert C. Radonski examined the problems confronting the marine recreational fishing industry. Tackle manufacturer Richard J. Kotis discussed and recommended strategies for a strengthened fishing tackle industry.

Panel 3, chaired by Bartlett Theberge, focused on angler needs. Anthony Fedler examined the motivations for marine angling, how they were related to satisfaction in angling, and discussed resultant management and development implications. Charles J. Moore discussed the data available, and the information needs of marine anglers and the role of providing that information in fisheries development and management. And, Michael P. Voiland, Jr., outlined needs and new initiatives for coastal fishing access.

Panel 4, chaired by John M. Green, dealt with the potential for expanded utilization of fisheries resources. John Boreman, Michael P. Sissenwine, Merton C. Ingham, and Wallace G. Smith examined opportunities for MRF enhancement; Jay D. Hair discussed habitat constraints on MRF and how to enhance habitat; Peter A. Larkin provided a look at the role of development in fisheries management; and Ronald L. Schmied reviewed the tools and methods for marine recreational fisheries development.

Panel 5, chaired by Robert E. Stevens, was keyed to "Development and the Management Process." James T. Barrett reviewed some of the challenges of fisheries development for fisheries managers; James A. Timmerman, Jr., discussed the institutional constraints on MRF development; and Donald L. Schultze and Robert C. Fletcher discussed the integration of interests of marine anglers with marine interests that impinge on marine angling and resources.

Finally, Panel 6, moderated by Frank E. Carlton, provided each Panel chair-

man's recommendations for action—the summaries of the views of the various panelists and audience from the Chairman's perspective as summed up and elaborated on by the Panel chairmen. The volume represents an excellent summary of the problems, dilemmas, challenges, and opportunities for the development of marine recreational fishing. Hardbound, the 218-page volume is available from the IGFA for $15.00; all nine volumes are available for $50.00.

Studying the Gray Whale

"The Gray Whale, *Eschrichtius robustus*," edited by Mary Lou Jones, Steven L. Swartz, and Stephen Leatherwood and published by the Academic Press, Inc., Orlando, FL 32887, contains a wide range of excellent contributions from scientists working in Canada, Japan, Mexico, the United States of America, and the Soviet Union. It is a fine up-to-date compendium of information on the species.

Sole member of the family Eschrichtiidae, the gray whale is considered by many to be the most primitive living baleen whale and it is important for many reasons—economically, aesthetically, scientifically, etc. Much work has been done on it since publication of Rice and Wolman's "The Life History and Ecology of the Gray Whale" in 1971 and the 1974 special issue of the *Marine Fisheries Review*, 36(4):1-64, which was devoted to articles on "Gigi," a young captive gray whale studied for a year and then released.

This new volume presents articles in Section I on gray whale evolution, fossils, and subfossil remains from both the Pacific and Atlantic Ocean areas, the latter indicating that the species was taken commercially in American colonial times. Section II documents historical relationships and exploitation by the Japanese and by American Indians, and describes early and modern commercial pelagic hunting of gray whales by Norwegians, Soviets, Japanese, and Americans. Included is important data on and analyses of ethnographic, historical, and archaeological aspects of gray whale hunting.

A third section reviews current knowledge on gray whale demography, distribution, and migrations: Stephen Reilly reviews efforts to assess gray whale abundance; David Rugh reports on censuses at Unimak Pass, Alaska, Nov.-Dec. 1977-79; Howard Braham thoroughly reviews distribution and migration of the species in Alaskan waters; and James Darling reports on gray whale studies off Vancouver Island, B.C. Other contributions discuss migration research along the Oregon coast (1978-81); demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico; the gray whale's reoccupation of Laguna Guerro Negro, Baja California; their migration corridors along the central California coast, 1980-82; and Soviet studies of distribution and numbers in the Bering and Chukchi Seas, 1968-82.

The final section, on biology and behavior, presents papers on gray whale feeding ecology, foraging along Vancouver Island's west coast, a review of Soviet research on the species' biology and commercial whaling, a report on investigations of gray whales taken in the coastal waters of Russia's Chukchi Sea, gray whale sound production studies in winter and summer ranges, dive characteristics and movements of radio-tagged gray whales in San Ignacio Lagoon, and ocean movements of radio-tagged gray whales.

While the gray whale returned to healthy numbers, it has also been very accessible to researchers. This volume reflects the results of many important research programs and will be a valuable reference. Indexed and well illustrated with maps, photographs, and much original art, the 600-page hardbound volume is available from the publisher for $75.00.

Edible Marine Animals of the Pacific Coast

"The Printers Catch," subtitled "An Artist's Guide to Pacific Coast Edible Marine Animals," has been published by Sea Challengers, 4 Sommerset Rise, Monterey, CA 93940. The author, Christopher M. Dewees, is a marine resources specialist with the Univerity of California at Davis.

The 112-page volume, 10″ × 8″, is handsomely printed and is a nice combination of art and natural history, perhaps most interesting for its utilization of genuine fish prints or "gyotaku," the Japanese art of fish printing revived in the United States by some NOAA Sea Grant programs. Since all the original fish prints, done on handmade oriental papers, are made directly from the fish itself, an exact image is produced.

Thus, the volume is more than a simple field guide. The author has covered 32 of the most important fish families of the Pacific coast, (including several mollusks and crustaceans). For each, he has also provided pertinent data on the particular species' life history, fisheries, and consumer information. In addition, he provides historical data on gyotaku, tells how to do it, and lists sources of supplies. Also included is a glossary of fishery terms, illustrations of fishing gears, and a list of references for more detailed information on the various species.

In all, there are 43 color and 22 black and white illustrations for species ranging from various Southern California kelp bed fishes, to albacore, white sturgeon, and yellowtail, and including several rockfishes, Pacific salmon, northern anchovy, lingcod, sculpins, abalone, squid, Dungeness crab, spot prawn, cabezon, halfmoon, pile perch, Pacific barracuda, wolf-eel, rock sole, and more. The hardbound volume is available from the publisher for $26.95.

The Care, Preservation, and Cooking of Sharks

One of the most thorough books on shark utilization is **"Cook's Book, A Guide to the Handling and Eating of Sharks and Skates,"** by Sid Cook, published by G. A. Bonham, Corvallis, Oreg. The author, a consulting scientist, has had wide experience with sharks, including fishery development, shark studies and electronic tracking, etc., and sport fishing for sharks.

Well illustrated, the volume provides

historical references and up-to-date data on shark eating and attitudes toward sharks, how to purchase shark (and common varieties available by region), how to butcher and handle fresh-caught sharks and skates, urea removal, preparation of and cooking methods for fresh and thawed shark; freezing, smoking, salting, and drying shark; and nutritional values of shark.

A section on shark cookery provides 50 tested recipes for shark and skate varying from Teriyaki Shark, Ginger Shark and Requin Provencale to Boiled, Broiled, Poached, Curried, Steamed, and Barbecued Shark, and more. Also listed is Ray in Caper Sauce, a traditional French recipe, and directions on making imitation crab from skate.

Appendices provide directions on preparing shark jaws and teeth as mementoes of the catch, removing and preparing shark fins for personal or commercial use, preparation of shark hides, and, finally, selecting wines to serve with shark. All in all, the book is an excellent compendium of data on sharks for the consumer, angler, and commercial fisherman. Indexed and referenced, the 106-page paperback volume is available from Cook's Book, 1023 N.W. 25th Street, Corvallis, OR 97330 for $10.95 ($12.95 for international orders payable in U.S. funds). A special waterproof version which resists the marine environment and weather elements is available at $17.95 (and $19.95).

The Movement and Migration of Fishes

Publication of **"Fish Migration"** by Brian A. McKeown has been announced by Timber Press, P.O. Box 1631, Beaverton, OR 97075. The author is a Professor in the Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada.

The author begins by defining "migration," and discusses migration direction, periodicity, distance, speed, duration and degree of return, and reviews the basic methods for studying fish migration. A second chapter reviews the various patterns of fish migration; a third discusses the means, methods, and cues that fish utilize for orientation. Additional lengthy chapters deal with the bioenergetics and physiology involved in fish migrations. Finally, the author reviews ecological and evolutionary factors involved in fish migration. Major portions of the text are devoted to orientation, which includes discussion of the initiation of cues and means of navigation, and to physiological adaptations required for migration.

The patterns of migration discussed include those of the many diadromous species, as well as those of potamodromous fishes, such as kokanee salmon and certain trouts and suckers. Further, the author reviews the migrations of such species as cod and herring. Covered is work up to about 1983 on the topics of orientation, bioenergetics, migratory patterns, behavior, ecology, and evolution.

Fish migration is a topic of considerable interest and use to fishery scientists and managers, and this volume is the first major review of the topic since 1968, and incorporates the discussion on physiological aspects lacking then. The 224-page hardbound volume is amply illustrated with 73 drawings and maps, 14 photographs, and has many tables and a large bibliography. It is available from the Timber Press for $29.00 and will be of interest to fishery researchers and managers, as well as to students of the behavioral aspects of migration.

More specific is **"Olfactory Imprinting and Homing in Salmon,"** by A. D. Hasler and A. T. Scholz, published by Springer-Verlag New York, Inc., 175 Fifth Avenue, New York, NY 10010. It is subtitled "Investigations into the Mechanism of the Imprinting Process," and is based in large part on Scholz's doctoral dissertation, but goes further to trace the evolution of ideas and experiments and focus on fairly recent investigations into olfactory imprinting and homing and the role of endocrines in that process.

The monograph is organized into two parts, with Part I reviewing general information on Pacific salmon life history (especially the coho salmon, *Oncorhynchus kisutch*), evidence for imprinting, early investigations of imprinting to olfactory cues, experiments with artificially imprinted salmon, natural imprinting, mechanisms of olfactory orientation in upstream migration, and pheromones and homing.

Part II presents, in Chapter 3, a comprehensive review of smolt transformation, including descriptions of the morphological, physiological, and behavioral transitions and control of this metamorphic process. Chapter 4 discusses fluctuations in hormone levels during the spawning migrations and the effects on olfactory sensitivity to imprinted odors. Chapter 5 then discusses thyroid activation of ofactory imprinting in coho salmon and Chapter 6 considers endogenous and environmental factors that influence smolt transformation.

In addition, the authors have provided an interesting review of the general impressions that they have formed on the life history, behavior, physiology, and ecology of salmon over many years of study. Thus, the monograph is something of a chronological account of the author's and their associates' investigations and the evolution of their experiments, investigations, beliefs, and hypotheses.

The book is Volume 14 in the publisher's Zoophysiology series which also includes "The Ethology of Predation" by E. Curio (vol. 7) and "Diversity and Adaptation in Fish Behavior" by M. H. A. Keenleyside (vol. 11). Indexed and with an extensive list of references, the 134-page hardbound volume is available from the publisher for $29.00.

On the Management of Marine Fisheries

"Fishery Management," by J. L. McHugh is Volume 10 in the series "Lecture Notes on Coastal and Estuarine Studies," published by Springer-Verlag, 175 Fifth Avenue, New York, NY 10010.

The volume reflects the author's many years of fisheries teaching at the State University of New York's Stony Brook campus and his interest in the philosophy and practice of fisheries management. He provides very broad, if often brief reviews of many aspects of U.S.

marine fisheries and the way they are or have been managed, and the book is essentially a series of case histories chosen to reflect various successes or failures in marine fisheries research and management, including those of several international bodies.

In 19 chapters, the author discusses marine fisheries research, the U.S. fisheries as a whole, the oyster industry, blue crab fishery, the Pacific sardine and Atlantic manhaden industrial fisheries, marine sport fisheries, interstate marine fisheries compacts, the International Whaling Convention, International Pacific Salmon Convention, North Pacific Fur Seal Convention, and the International Convention for the High Seas Fisheries of the North Pacific Ocean, and others. In addition, he reviews fishery oceanography and fishery economics, and a final summary chapter highlights the significant aspects of the book and provides several suggestions for improving marine fisheries research and management. Included are species and subject indexes; the 207-page paperbound volume is available from the publisher for $17.00.

Classic Marine Survival Guide Revised, Expanded

The fourth edition of **"How to Survive on Land and Sea,"** has been published by the Naval Institute Press, Annapolis, MD 21402. Originally authored by Frank C. Craighead, Jr., and John J. Craighead, this latest edition has been revised and updated by survival experts Ray E. Smith and D. Shiras Jarvis. The original was issued by the Aviation Training Division of the office of the Chief of Naval Operations in 1943.

This new edition has been expanded, often with information developed either by or for NOAA agencies, and is divided into three parts: Water Survival, Land Survival, and Natural Disasters Survival. The sections dealing with cold water and seashore survival, water survival, abandoning ship and survival swimming, and environmental hazards at sea will be most useful to those who work on or study the sea. Of additional value are the sections on natural disaster survival and first aid, land survival; plant, animal, and fish foods; fire-making and cooking, travelling, environmental hazards, tropical rain forest survival, and desert survival.

The authors have brought the book up to date on the latest methods for coping with hypothermia and other aspects of surviving hazardous climates and situations. The introduction discusses establishing survival priorities, mental strength and physical readiness, realistic assessment of abilities, preparation of survival kits and medication needs, and signalling, including material on ELT, EPIRB, and the SARSAT system concept.

Also included is a folded map of the world's principal vegetative regions and the world distribution of natural hazards, showing iceberg drift areas, earthquake epicenters, tropical storm tracks, volcanoes, and areas of likeliest tsunami impact, tornado occurence, winter and monsoon gales of Beaufort 7 and greater at least 30 percent of the time in season, greatest tropical storm incidence, and thunderstorms (more than 100 days per year).

Indexed, the volume also presents general and specific bibliographies for those wanting to locate original sources of survival data. The 414-page softbound volume is available from the publisher for $14.95.

Developing and Marketing U.S. West Coast Squids

"Proceedings of the West Coast Squid Symposium," prepared by the West Coast Fisheries Development Foundation (WCFDF) and the Oregon State University Sea Grant Marine Advisory Program, presents the record of the 1983 meeting on the *Loligo opalescens* resource, pertinent fishing techniques, marketing strategies, and much more. Participants included many U.S. experts in squid harvesting and marketing, as well as commercial fishermen and squid biologists.

Presentations included papers on *Loligo* distribution, biology, and life history; east coast squid fisheries, California's squid fishery and light fishery; and on squid trawling gear, jigging gear, and techniques for their use. The volume also includes informative panel discussions of Japanese squid fisheries, development of Oregon's squid fishery, squid handling and processing for export markets, processing automation, and developments in squid marketing. An appendix presents selected local and world squid landing statistics. The 150-page paperbound volume presents much useful information for those interested in getting started in fishing for or marketing squid and is available from the WCFDF, 812 S.W. Washington, Suite 900, Portland, OR 97205 for $6.00.

The Study of Sticklebacks

Publication of **"A Functional Biology of Sticklebacks"** by R. J. Wootton has been announced by the University of California Press, 2120 Berkeley Way, Berkeley, CA 94720, as the second volume in its Functional Biology Series. The author, Lecturer in the Department of Zoology, University College of Wales, utilizes his own research into stickleback biology and ecology and many other studies to provide succinct reviews of stickleback distribution, habitats, and migrations; their morphology and anatomy and systematic position; foraging and feeding characteristics; effects of environmental factors on sticklebacks and their metabolism and energetics; reproduction, growth, and production; interspecific relationships, population dynamics, ecological genetics, and life history strategies.

Sticklebacks have figured in many studies of fisheries ecology and ethology and this volume is a fine review of how these species utilize spatial habitat, food supplies, etc., and the patterns of growth, survivorship, and reproduction that result. It integrates physiological, ethological, and ecological characteristics to show how the stickleback is adapted to and succeeds in its environment. Indexed and with extensive references, the 265-page hardbound volume is available from the publisher for $29.75.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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